United States

Department of Agriculture

YEARBOOK *of* AGRICULTURE

1936

74th Congress, 2d Session

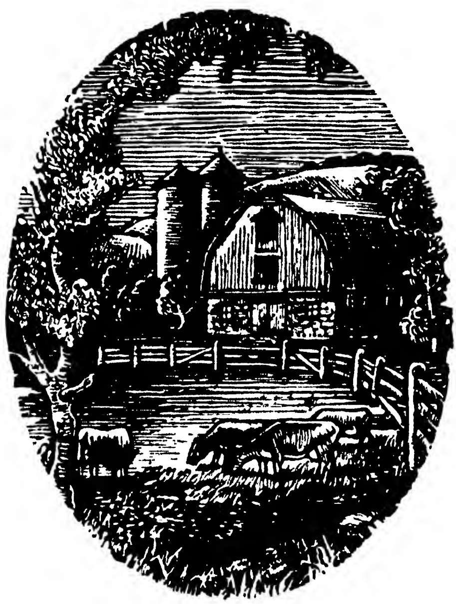
House Document No. 338

UNITED STATES

GOVERNMENT PRINTING OFFICE

WASHINGTON: 1936

YEARBOOK OF AGRICULTURE



✧ 1936 ✦

UNITED STATES

DEPARTMENT OF AGRICULTURE

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of the United States Department of Agriculture

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Foreword

THE *1936 Yearbook of Agriculture differs in two ways from those published in recent years.*

For some time past the book has presented brief summaries of miscellaneous new developments in agriculture. This year it is devoted to exploring a single subject—the creative development of new forms of life through plant and animal breeding. The material is the outcome of a survey of superior germ plasm made by the Committee on Genetics. What this superior germ plasm is and how it is used constitute a story of surpassing importance to the modern world.

Most of the voluminous statistics usually gathered together in the Yearbook are here notably absent. These statistics, the tail of the book, had grown so large that they were wagging the dog. They have been severed, and beginning this year will be published in a separate volume. Primarily of use to specialists, they should be even more useful in the new form.

One other matter needs explanation. The Secretary's Report to the President, which is given precedence in the Yearbook, deals largely with a situation that is now past. When, on January 6, 1936, the production control programs were stopped by the decision of the Supreme Court in the Hoosac Mills case, the agricultural picture was necessarily changed.

In providing for wise land use and the conservation of soil resources, the new program is a significant step forward. In a real sense it is an outgrowth of the old production control programs, which had increasingly stressed soil conservation and the sound use

of land. But whereas control of production and price was then the primary aim and soil conservation the byproduct, now soil conservation is primary and any effect on the supply and price of individual farm commodities will be a byproduct.

But the factors that necessitated production control still exist. With normal weather and normal yields the acreage of cultivated crop land in the United States is still capable of producing surpluses beyond the available domestic and foreign outlets. If such surpluses recur the need for production control is likely again to become acute. In that event, the provisions of the new act for Federal aid to the States, to take effect not later than January 1, 1938, for the carrying out of production control as well as soil conservation, may prove to be highly significant.

HENRY A. WALLACE,
Secretary of Agriculture.

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The Year in Agriculture

Report of the Secretary of Agriculture to the President of the United States • Washington

December 10, 1935

FARM RECOVERY AIDING GENERAL RECOVERY

IT IS evident from the language of the Agricultural Adjustment Act that Congress intended the legislation to benefit our economy as a whole, and to invigorate urban industry as well as agriculture. The purpose of the act, in short, is to promote a balanced abundance. It stipulates that the interests of consumers shall be protected and that cordial relations shall be established between town and country. Those who drafted the legislation did not conceive that relief to agriculture would mean damage to other legitimate interests or that the removal of one injustice would create another. They projected a farm program calculated to harmonize farm welfare with general welfare.

The Agricultural Adjustment Administration programs have definitely advanced us toward this goal. Their primary aim has been to allow for the decline in agriculture's foreign market. That has been accomplished. Last year's drought reduced the production of feed, livestock, and dairy products more than was desirable, but the Agricultural Adjustment Administration took steps at once to mitigate the consequences of the drought to consumers as well as to producers. It modified the farm-contract requirements so as to step up production in the lines in which the drought had cut it down too much. As the framers of the law expected, the partial restoration of farm incomes has stimulated rural buying and consequently helped urban industry.

In working toward these ends agriculture has not sought to create domestic shortages. There is a shortage of hogs just now, but action is going forward to correct it. Throughout the depression farmers have supplied the country with an even flow of goods for processing and domestic consumption. From 1931 up to the present time the volume of manufacturing output processed in the United States from domestic raw materials has remained at approximately 90 percent of

the 1929 level. Even this moderate reduction, moreover, is not the result of the farm programs. It is attributable mainly to the failure of the textile industries to consume their normal volume of fibers. The cotton supply available is more than ample.

For the current crop year the supply of most food crops is fully adequate, certain classes of wheat being the only exception. There are rather large crops of rye, beans, potatoes, sweetpotatoes, and sugar beets. Potato production is about average; the production of buckwheat and rice, though below normal, is sufficient; we have average fruit crops rather evenly distributed, except that citrus production is light in the Gulf States; the production of vegetables for canning is close to or above previous records, and supplies of market vegetables and truck crops are moderately heavy in some areas and excessive in others. Dairy production this year was substantially greater than in 1934. Normal growing conditions in 1936 may confront agriculture once more with the problem of surpluses.

No Injustice to Consumers

Consumers have suffered no injury from the farm programs, as may be judged from the farm-commodity price level. Farm commodities in August 1935 averaged only 6 percent above the pre-war level, whereas the prices of the things that farmers usually buy were 26 percent above pre-war prices. In considering the recent sharp advance in consumers' prices it is necessary to bear in mind the low point to which agricultural prices had previously declined. Fair returns to farmers do not involve unfair prices to consumers. Food prices in the spring of 1933 averaged only 60 percent of what they were in 1928. They are still only about 80 percent of the 1928 level. The average employed factory worker's earnings have also risen to about 80 percent of the 1928 level. Consumers can buy their usual quantities of farm products for one-fifth less money now than they could in 1928. Those who are unemployed find it difficult to pay their living costs; but the remedy for that situation is to increase industrial employment, not to hold farm commodity prices below the fair exchange value.

Moreover, farmers do not and cannot monopolize the benefits of farm recovery. The fact that industrial pay rolls and average earnings per employed factory worker have increased since 1933 in about the same proportion that farm incomes have increased is evidence that farm recovery promotes industrial recovery. It appears that about 4 out of every 10 persons reemployed in urban industry since the spring of 1933 owe the recovery of their jobs to the improvement in the farm situation. Statistical evidence compiled by this Department indicates that shipments of industrial goods to rural areas have increased proportionately with the advance in rural incomes. Farm recovery got under way in 1933 earlier than industrial recovery, and maintained its lead in 1934. Urban industry benefited promptly. For example, in towns of less than 10,000 population and on farms sales of automobiles in 1934 totaled 833,000, as compared with 602,000 in 1933. This was an increase of 231,000, or 38 percent. In cities of more than 10,000 population, on the other hand, sales of automobiles in 1934 were 1,055,000, as against 892,000 in 1933, an increase of 163,000, or only 18 percent.

Toward a Balanced Abundance

Continued farm recovery under the Agricultural Adjustment Act should carry us further toward the ideal of a balanced abundance and should promote a fuller utilization of our human and material resources. Recovery from last year's drought is under way. As consumer-buying power increases with revived industrial activity and lays a foundation for a higher national standard of living, the crop programs will provide for increased production for domestic consumption. Farm incomes will increase because farmers will have more to sell at a fair price, and consumption per capita will be higher. Manifestly, however, the task of establishing a balanced abundance is not the sole responsibility of the farmers; indeed, it is not even mainly their responsibility.

Agriculture is not the laggard in production. In August 1935 factory employment in this country was nearly one-fourth lower than it was in 1928, and about one-fourth of the urban population that should have been employed was not. But most of the factory unemployment was in the factories processing industrial, not farm products. Factories processing farm products employed in 1934 about 82 percent as many wage earners as they did in 1929, whereas the factories processing nonagricultural raw materials employed 30 percent less labor than in 1929. Most of our agricultural, industrial, and fiscal difficulties would be solved if the manufacturing branches of industry were operating as freely as the agricultural. From the standpoint of domestic requirements, agriculture. in contrast with industry, has maintained its output.

In a truly balanced economy industrial production would outstrip farm production, for it should be remembered that a price disparity prevailed against agriculture even in the predepression years. This means, of course, that agricultural production was then relatively greater than industrial production. With agriculture continuing to supply the domestic market abundantly, as it fully intends to do, parity prices for agriculture would require an industrial production level at least 10 percent higher than that of 1929.

On a per capita basis the United States has recovered half the depression loss in the physical production of consumers' goods, and one-third of the depression loss in the physical production of capital goods. In August 1935 the per capita production of goods for sale to consumers (including automobiles) was 84 percent of the 1929 level, as compared with 72 percent in 1932. Our production of capital goods in August 1935 was 53 percent of the 1929 level, as compared with 27 percent in 1932. Though they reduced the farm output, the Agricultural Adjustment Administration programs contributed to the total gain. This apparent contradiction is the result, of course, of the stimulus that farm recovery imparted to nonfarm industries and to the fact that Agricultural Adjustment Administration's efforts were directed at restricting production not of goods for domestic consumption but of goods for which a satisfactory foreign market no longer existed. When farmers stopped producing for vanished export markets, farm-cash income increased, the country demand for city goods revived, and urban employment mounted. Nevertheless, industrial production in 1935 was still only 74 percent of what it was in 1929, whereas farm production was 88 percent of the

1929 level. This disparity is the more striking when we reflect that agriculture through the decline in foreign trade has suffered much more than industry from a shrinkage in its total market. Relative to the demand, agriculture is producing far more abundantly than urban industry.

Other Essentials to Recovery

That full industrial recovery will require some additional stimulus is evident. Our population is now 5 percent larger than it was in 1929. Had the production trend of the predepression period (with production growing faster than population) been maintained, the physical output for 1935 would be considerably greater than that of 1929. Actually, as already noted, it will be about 25 percent less. Yet even in 1929 our actual production was far below our production capacity, just as our real consumption was below our consumption needs. Federal action taken to protect consumers, to provide economic security, and to redistribute tax burdens, should help toward continued expansion in both production and consumption. These policies tend to increase the proportion of the national income going to persons in the lower income brackets, and therefore to increase consumption per capita. Other national policies, such as those implemented in Public Works Administration, Works Progress Administration, Home Owners' Loan Corporation, Federal Housing Administration, and Farm Credit Administration should help. All these constructive influences combined, however, may fail to revive industrial production sufficiently in the absence of a coordinated effort for general expansion.

As is well known, our efforts up to the present to coordinate recovery have dealt separately with separate industries. The Agricultural Adjustment Act has dealt with agriculture, the Guffey law with coal, the National Recovery Act with different branches of industry each under its own separate code. The proposed Ellenbogen bill for textiles goes on the same principle. Such measures, each dealing with an individual industry, in seeking to raise the income of that industry, must depend in the last resort on restriction of output to what the market will take at the prevailing level of purchasing power. Should one industry attempt, independently of the others, to run at capacity it would not find an increased market. But were all the major industries to expand together, the total market would grow with the total production; buying power and production would expand together. Partial coordination, undertaken from the standpoint of individual industries, must give place to a general, comprehensive coordination aimed at increased production and increased pay rolls, if we are to have full employment, full production, and higher living standards. How to achieve coordination for balanced expansion is the problem which awaits solution.

PERMANENT AGRICULTURAL ADJUSTMENT

Almost everyone recognizes that American farmers had perforce to act in concert under Federal guidance to meet the situation that developed after the crisis of 1929. With foreign markets blocked and domestic buying power low, huge supplies of the main farm

products had piled up in storage. The prices of these products had fallen to a point far below the pre-war level, though the prices of things bought by farmers were still about 24 percent higher than before the World War. This enormous disparity between the prices received and the prices paid by farmers threatened them with wholesale bankruptcy. Thousands could not pay their debts or taxes, keep up their farms, or properly shelter, feed, and clothe their families. It was imperative to scale down the farm output in accordance with the reduced foreign demand and to organize the retreat from overproduction so as to prevent it from becoming a rout. Drastic action was necessary at once. Accordingly, farmers generally, and also the Nation as a whole, approved the crop-adjustment programs, which under the Agricultural Adjustment Act brought supplies into a better relationship with the shrunken market.

In the 2½ years that have elapsed since the passage of the Agricultural Adjustment Act the farm surpluses have largely disappeared. Cotton is still present in quantities much above immediate requirements but supplies of grains and livestock products are no longer excessive. Stocks of certain types of tobacco are still large. Dairy supplies are more nearly in line with the effective demand. Between 1932 and 1934 the production of 12 important crops declined more than one-third, and farm commodity prices rose. For the calendar year 1932 the prices of farm products averaged only 65 percent of the pre-war level. In March 1935 they averaged 108 percent of the pre-war level. These changes in production and prices, however, were only partly the result of the Agricultural Adjustment Administration adjustments and for many commodities were excessive. The drought of 1934 was very largely the cause. It would be wrong to conclude, therefore, that the need for crop adjustment had disappeared. On the contrary, it continued. Latent tendencies toward overproduction were still in evidence, which would become active immediately if foreign demand should remain stagnant and weather return to normal.

Shortcomings of the Emergency Methods

Certain shortcomings developed in the emergency adjustments which should be remedied in planning production control on a more permanent basis. In the drive for quick results, the effect on individual farmers could not always be carefully considered. Emergency adjustment contracts, as a matter of convenience, had to be based on the past production of individual farmers. That tended to make past production a sort of property right, to perpetuate maladjustments among farmers and regions, and to prevent desirable adjustments to changing economic, physical, and climatic conditions. Farmers made flat percentage cuts from their historic production base. Such flat-percentage adjustments tended to give the highest base to farmers who had responded slowly to the changed market conditions after 1929 and to penalize farmers who had responded more promptly to the reduced demand. Moreover, the emergency adjustments tended to freeze farm production in the historic mold, in violation of efficient practice. Many farmers, though approving of the adjustment program as a whole, were dissatisfied with some of the details.

In the second adjustment season the Agricultural Adjustment Administration modified its regulations to eliminate hardships that would have resulted otherwise, gave farmers more freedom in combining their various crop enterprises in harmony with the crop-adjustment programs, and began to make the adjustment procedure more flexible. Essentially, however, it retained the commodity approach, pending closer study of the problems involved in adapting the crop adjustment as a whole to the special conditions of various regions, localities, and individual farmers. In long-time adjustments it seems desirable to develop a regional basis, so as to avoid conflict between adjustment quotas and the principles of good land use, balanced farming, and sound farm management. Otherwise it will be difficult to combine the fair treatment of individual farmers with necessary changes in the localization and production of crops.

Analysis of productive capacity on the one hand and of consumption possibilities on the other (barring an altogether improbable immediate reduction in international trade barriers) shows that an interlude in production control would soon throw our farm economy into chaos again. Not all the forces that produced the great surpluses of 1929 are still in operation. Foreign lending by the United States has practically ceased, and prices no longer justify great expansion. Foreign countries, moreover, deliberately exclude our goods instead of receiving them willingly. Overproduction on a predepression scale is not likely to recur quickly under such handicaps. It may readily recur to a material extent, however, partly through natural recovery from the drought and partly through the incentive farmers always have to produce as much as possible. In a purely competitive situation individual farmers cannot hold back, though they may fully realize that collectively the result of not doing so will be bad.

Our Acreage Requirements

How much farm production do we need for domestic use and for export? In the period 1928–32 the actual acreage of crop land harvested in the United States averaged 360,000,000 to 365,000,000 acres; and this area is much above that required, at average yields, to supply the present market, domestic and foreign. The necessity for continued farm readjustment is evident. The scale of the required change puts it beyond the scope of individual competitive action. Any attempt to dispense with concerted crop adjustment for the time being, on the theory that the adjustments so far accomplished do all that is necessary, would quickly come to shipwreck. Only a renewed opportunity for unimpeded export would give such an attempt a fighting chance. The opportunity for unlimited farm expansion in the United States is definitely over.

From 1919–20 through 1932–33, in years of depression as well as in years of relative prosperity, the average per capita consumption of foodstuffs in the United States was remarkably stable. Estimated in terms of weights sold in the retail market it averaged about 1,422 pounds for the period 1920–24, about 1,474 pounds for the period 1925–29, and 1,454 pounds for the period 1930–33. Total pounds of food used is not an ideal measure either of consumption or of changes in consumption, but it reflects the trend. The consumption per capita of different groups of food products is almost as stable as

that of all groups combined. It seems fair to take the period 1925–29 as a standard for gaging requirements for the immediate future, because this period was as prosperous as any that the United States has ever known.

Assuming continued imports of such commodities as sugar and coffee, it would require from 285,000,000 to 290,000,000 acres to supply our present population with the same per capita consumption of food as prevailed in 1925–29. Consumption per capita of the nonfood products, such as cotton, wool, tobacco, and flax, varies more than the consumption of food. To supply our present population with nonfood products at the 1925–29 level would require about 25,000,000 harvested acres. On a liberal estimate, therefore, we need perhaps 310,000,000 acres adequately to supply the home population with food and nonfood products.

The acreage requirement for export is declining. Our wheat exports for the season 1934–35 were even smaller than the 37,000,000-bushel total in 1933–34, which may be instructively compared with the 370,000,000 bushels exported in 1920–21. Exports of pork and lard in 1934–35 were likewise lower than in the preceding year when they totaled only 700,000,000 pounds as compared with nearly 2,000,000,000 pounds in 1923–24. Our exports of cotton and tobacco have been maintained at a more stable level. Exports of cotton, nevertheless, were materially reduced in 1934–35, and exports of tobacco did not exceed two-thirds of what they were in 1929–30.

The acreage required at average yields to supply our exports dropped from 84,000,000 in 1920–21 to 39,000,000 in 1933–34. With foreign trade blocked as it is by tariffs, quotas, embargoes, quarantines, subsidies, and such restrictions, the most that can be expected is a gradual increase. Probably we cannot count, for the immediate future, on an export demand for the production of more than 30,000,000 to 40,000,000 acres. All told, therefore, we shall not need more than 340,000,000 to 350,000,000 acres to supply the probable demand for home consumption and exports combined.

The difference between this figure and the actual acreage harvested prior to the depression does not represent the entire potential excess. By no means all the land available for harvest was actually harvested then. It would be possible, even without increasing the area in farms, to raise the harvested acreage considerably above the average (360,000,000 to 365,000,000) for the period 1928–32, since most farmers have more land that they could bring under cultivation were they so inclined.

Acreage Adjustment Methods

The necessary acreage readjustment can be accomplished, theoretically, in several ways. One way would be entirely to cease cultivating a certain amount of land. On an extremely conservative estimate this course would necessitate leaving idle from 10,000,000 to 25,000,000 acres. Another way to make the adjustment would be to shift much land from intensive crops such as cotton, corn, and wheat, to pasture, hay, and forage crops; in other words, to reduce the intensity of cultivation. On this basis a shift of 20,000,000 to 40,000,000 acres would be required. Still another way to balance production with the anticipated demand would be to retire submarginal

land. That would involve the biggest shift of all, and would involve perhaps 50,000,000 acres.

In some areas the production of certain crops should increase. In other areas, particularly areas subject to severe erosion, cash-crop production should decline and farming should be shifted to a more extensive basis. Again, some areas have soil so poor that farming will not provide a good living under the best economic conditions. Past production in such areas is an unsatisfactory guide in making crop adjustments. Even in the first year's operations the Agricultural Adjustment Administration recognized the importance of allowing farmers some latitude in selecting the type of adjustment best suited to their individual farms. The tobacco contracts particularly permitted considerable flexibility in adjustments. In 1934 local committees in certain western wheat counties took individual farm-management practice into account in allotting quotas.

The 1935 corn, hog, and cotton programs provided for flexibility in allotments. Participating farmers, instead of having to make a flat percentage adjustment in their output, had the right to choose within a considerable range the adjustment best suited to their farms. Also the Agricultural Adjustment Administration encouraged erosion control and soil improvement by permitting land taken out of the production of basic crops to be used for soil-improving and erosion-preventing crops. Broadly, the object of a long-time farm-adjustment program should be to promote and encourage the best utilization of the individual farmer's resources, and at the same time to adjust farm production as a whole to yield the maximum farm income over a period of years. Essential to the program would be action to conserve soil fertility and to find other than farm uses for land not suited to farming.

Advantages of Regional Approach

Crop adjustment on a regional basis would still be on commodity lines, to some extent, because of the geographical distribution of our principal crops, but it would allow for the important differences that exist in the farming practices of different areas. It is important to encourage sound rotation practice and to have the production of each farm managed so as to permit the most efficient use of machinery, tillage methods, and fields. Adjustments regarding wheat, for example, should not be identical for all farmers, no matter where they live or whether they specialize in wheat or simply raise it as part of their rotation. The same is true of cotton, corn, and hogs.

With a view to the better adaptation of the Agricultural Adjustment Administration programs to varied regional and local conditions, the Program Planning Division has begun a study for the purposes of which it has divided the country into 12 major agricultural regions, among which are the Corn and Cotton Belts and the wheat, range livestock, dairy, and other regions. Each of these regions has problems distinct from those of the others, and the regional problems must be considered separately and also in their interrelationship. By this means it is hoped, through close contact with farmers and with the cooperation of State agencies, largely to decentralize adjustment planning without sacrificing the objects of

a coordinated national program. The problem, after determining the desirable volume of production for the important farm commodities, is to divide the total fairly among the different regions, with an eye to long-time as well as immediate benefits, and then to allocate the production equitably among individual farmers.

This undertaking involves many difficulties, notably that of smoothing out interregional conflicts. As is well known, farmers in some States produce commodities for sale largely, not to the consumer in the first instance but to farmers in other regions. Thus the Corn Belt supplies feeds to the dairymen of the Northeastern States. These two groups of farmers, the one desiring to sell dear and the other desiring to buy cheap, cannot easily reach the same conclusion as to how much feed grain the country should produce. It can be shown that they have, at bottom, a substantial identity of interests. There is no ultimate advantage in excessively cheap feed to the dairy States; for the effect is to overstimulate dairy production, not only in the principal dairy States but throughout the country, and hence to make both feed growing and dairying unprofitable. But this is a farsighted view that farmers do not commonly recognize in the heat of their competitive struggles, and to give it scope in regional planning will require much study and thoughtful consideration and discussion. No central authority can impose a cut-and-dried plan. Only through processes essentially democratic, whereby all farm interests receive equal and adequate attention, can agriculture deal efficiently with the problem of regional adjustment.

But it should not be forgotten that the alternatives are difficult also, and less satisfactory. Essentially there are two: (1) A return to the old free-for-all; or (2) retention of the strictly commodity approach, with such modifications as it may permit. For the reasons already given, the relapse of American agriculture into blind unrestrained competition is unthinkable in the existing circumstances. As for the other alternative, retention of the strictly commodity approach in crop planning, it is certainly not less fraught with possibilities of individual and regional dissatisfaction than the more logical regional system. Essentially, the choice is not between cooperative crop adjustment or the repudiation of it, but simply a choice as to methods to be used in continuing some production control.

Federal and State Cooperation

In the first steps toward a regional approach to the adjustment problem, the Department sought the cooperation of the State agricultural experiment stations in getting a better description of regional and area differences in agriculture. Previously, the experiment stations had been less active than the extension forces in the adjustment work. Regional adjustment requires detailed knowledge such as only the experiment stations can adequately supply; knowledge, for example, about regional and local matters such as the size of farms, the distribution of crops by areas within States, the choice of enterprises on individual farms, the local aspects of soil conservation, and the bearing of all these factors on farm incomes. Regional conferences held last March in each of the major agricultural sections clarified the task greatly. The deans and directors of the agricultural colleges and experiment stations, the State extension directors,

and the heads of the economics departments in the various agricultural colleges, attended the conferences. The idea was to develop recommendations first on a State and regional basis, and then in a coordinated national form, for agricultural adjustment to promote good land use; and finally to harmonize this technical purpose with satisfactory economic results.

The experiment stations adopted the program, and with funds supplied partly by the Agricultural Adjustment Administration began the necessary descriptive analyses. They differentiated their States into areas having similar types of farming, similar soils, crops, etc.; recommended changes considered desirable from the standpoint of soil conservation and good farm practice; estimated the probable effect on production and gross income, assuming various price levels; and developed adjustment objectives for dovetailing across State lines with the recommendations of other States having similar agricultural problems. Essentially, the experiment stations sought to answer two questions: (1) Into what type of farming areas may each State be divided? (2) What adjustment in the prevailing enterprises in these areas would be necessary to maintain fertility, control erosion, and promote efficient management? Representatives of this Department cooperated with the experiment stations in harmonizing their procedures so that the findings in all the States would be approximately comparable.

In August and early September the States presented tentative conclusions as to the adjustments desirable within their own boundaries. They based these conclusions on detailed information regarding the total areas in the different types of farming, the land in farms, the land in crops, the grazing and pasture land, the percentages of the crop land in various crops, the number of livestock on farms, and so forth. These conferences coordinated the State recommendations into regional reports. Sufficient progress was made to justify a start, in cooperation with the Agricultural Adjustment Administration, on plans for interregional cordination of cropping systems, with a view to developing the comparative advantages of different areas in a manner consistent with a sound national adjustment of agriculture to its physical and economic environment.

In the Corn Belt, adjustment centers around the feed grain-livestock problem and turns on the ratio of feed to grass and other crops that will best conserve land resources and give maximum net returns. In the small-grain region wheat is the center of interest. How many an over-extended cultivated area in wheat be adjusted to the restricted markets in prospect? In the range States the major concern is to differentiate the lands that can best be used for grazing and those that should be devoted to other purposes and to restore and maintain the productive capacity of the range. In the Southern States, where cotton and tobacco are the principal cash crops, the problem is to determine what acreages can be maintained without damage to soil resources and without oversupplying the available market. The problem of the dairy region is largely to determine a production and marketing policy in harmony with the domestic demand for dairy products and with the production adjustments that will inevitably go forward in other regions.

Positive Program for Good Land Use

The task is to plan our agriculture so as to give the desired production for the Nation as a whole and at the same time to permit the individual farmer in the different regions and areas to follow the farming system best adapted to his conditions and to his farm. In the initial stages of the Agricultural Adjustment Administration programs the emphasis was necessarily on reducing production. Now, that these efforts, with the added influence of drought in 1933 and 1934, have reduced agricultural supplies to nearly normal levels the emphasis in crop adjustment must be shifted. It must be positive rather than negative and must allow for certain increases in production as well as for desirable changes in cropping systems. This is a logical outgrowth of what has been done already. In long-time farm adjustment it is imperative to advance from the historic base principle, with its tendency to freeze production by areas and by individual farms in the accustomed mold, to a method better adapted to good farm management and good land use. The transition from flat-percentage reductions to differential adjustments makes the task more complicated, but has the great advantage of being both fairer and more scientific. Also it enlists the cooperation of the farmers in definitely constructive operations, as distinguished from mere efforts to raise prices by cutting down supplies.

Because of the innumerable factors involved, it is important to proceed cautiously before adopting future programs or before discarding programs now in operation. It is desirable, in other words, to build on the framework that has been developed already and to retain what has stood the test of practice. Incorporating the new principles into action programs is necessarily a slow and gradual process, and the steps that can be taken immediately will carry us only a little way toward the goal. As experience accumulates, the pace can be accelerated. The Agricultural Adjustment Administration has set itself to the task of overcoming the difficulties and has taken important steps to shape its new programs to a new and more flexible pattern.

SUITS AGAINST THE AGRICULTURAL ADJUSTMENT ADMINISTRATION

The year brought a widespread attack in the courts on the constitutionality of the Agricultural Adjustment Administration programs. The constitutional issues raised differ as to each of the different types of programs, although some common questions are involved in all. Three major types of administrative programs are being administered by the Agricultural Adjustment Administration:

1. The processing tax-benefit payment program, under which excise taxes are levied upon the processing of certain basic agricultural commodities and a sum equal to the proceeds of the taxes is appropriated for certain purposes including the making of benefit payments to farmers who voluntarily enter into contracts to adjust their acreage.

2. The marketing-agreement and order program, under which the Secretary of Agriculture enters into agreements with distributors and handlers of specified agricultural commodities and issues orders

binding upon them to prohibit unfair marketing practices, to regulate to varying extents the marketing of the commodities, and in the case of milk and its products to fix minimum prices to be paid by the distributors to producers. The Secretary is authorized to issue orders to enforce restrictions similar to those contained in such marketing agreements upon distributors and handlers whether they are parties to the marketing agreements or not.

3. The Bankhead Cotton Act, the Kerr Tobacco Act, and the recently enacted Potato Act of 1935, which authorize marketing allotments and impose a special tax on the marketing of the commodity in excess of allotments.

In the first case in which the constitutional validity of the processing tax was challenged (*Franklin Process Co.* v. *Hoosac Mills Corporation*), the Federal District Court in Massachusetts, on October 19, 1934, held the tax valid. While an appeal from this decision was pending, the Supreme Court of the United States handed down a decision in *Schechter* v. *United States*, in which case the National Industrial Recovery Act was held invalid, chiefly on the ground that it contained an unconstitutional delegation of legislative power. Apparently largely under the influence of this decision, the Circuit Court of Appeals for the First Circuit reversed the decision of the lower court in the *Hoosac Mills Corporation case* and held the processing taxes involved to be unconstitutional. As in the *Schechter case*, the chief ground was that the taxes had been imposed pursuant to an unconstitutional delegation of legislative power.

Amendments to the Law

In 1934 the Agricultural Adjustment Administration worked with committees of Congress in preparing amendments to the Agricultural Adjustment Act designed to simplify and facilitate its administration and to make possible the carrying out of the "ever-normal granary" plan. After the Schechter decision, the congressional committees revised these proposed amendments substantially, so as to define more explicitly the standards set up to guide and control the administration of the adjustment programs and to overcome the contention that the act improperly delegated legislative power. Congress passed the amendments as revised.

However, the decision of the Supreme Court in the *Schechter case* and the decision of the first circuit court of appeals in the *Hoosac Mills Corporation case* encouraged many processors to feel that the processing taxes might ultimately be declared unconstitutional. More than 1,100 suits were filed to prevent enforcement of the adjustment programs, most of them challenging the validity of the processing taxes. In a number of these cases temporary injunctions were issued to restrain the collection of the taxes. In a few cases decisions were rendered holding the taxes to be unconstitutional. By the end of September 1935 the suits had probably prevented the collection of about $100,000,000 in processing taxes.

The Constitutional Problem

The position taken by the Government on the constitutional questions involved may be summarized. The processing taxes are excise taxes, uniform in their operation both geographically and in their

incidence upon all processors in the same class, and levied under the tax power granted to Congress in article 1, section 8, clause 1 of the Federal Constitution; the appropriation of sums equal to the proceeds of the processing taxes for benefit payments to farmers voluntarily entering into contracts for the adjustment of production is a proper exercise of the general spending power of Congress and within the proper purpose of taxation which limits the exercise of the tax power. The section provides that "the Congress shall have power to pay and collect * * * excises to * * * provide for the * * * general welfare of the United States."

It is the contention of the Government that these appropriations are for a public purpose and for the general welfare inasmuch as the benefit-contract program is indispensable to the recovery of American agriculture and, therefore, indispensable to general national recovery from the depression. Moreover, the Government contends that the processing tax-benefit payment program does not contravene the tenth article of amendment to the Constitution (which reserves to the States and to the people powers not granted to the Federal Government) because the Congress is exercising only powers expressly granted to it in the Constitution—specifically, the taxing and spending powers.

Even if it be assumed that the Constitution does not empower Congress to regulate the volume of agricultural production, it does not follow that the exercise of powers indubitably granted to Congress in the Constitution becomes invalid merely because their exercise may accomplish something of the same result which might have been accomplished under a regulatory statute. In other words, where a given result may be accomplished in either of two ways, and the Constitution authorizes the Congress to utilize only one of those ways, the utilization of the authorized way does not become unconstitutional because the other way is not authorized. The tax provisions of the act, it is further argued, are separable from the appropriation of funds for benefit payments, and under the decisions of the Supreme Court, individual taxpayers may not challenge the validity of congressional appropriations.

Taxing and Administrative Provisions

Also, the Government maintains that the taxing and administrative provisions of the law are not unreasonable, arbitrary, or capricious, but have a real and substantial relation to the object sought to be obtained and hence are not wanting in due process of law. Finally, the Agricultural Adjustment Act clearly and explicitly defines the standards to be observed, so that it involves no improper delegation of legislative power, but merely a grant of circumscribed power to fill in the details and administer the programs.

In authorizing the Secretary to enter into marketing agreements with distributors and handlers and to enforce the agreements through administrative orders, the Congress is exercising the power granted to it in the Federal Constitution in article I, section 8, clause 3, "to regulate commerce with foreign nations, and among the several States."

The Agricultural Adjustment Act authorizes the execution of such marketing agreements "only with respect to such handling as is in

the current of interstate or foreign commerce or which directly burdens, obstructs, or affects interstate or foreign commerce in such commodity or product thereof."

The Bankhead Cotton and Kerr Tobacco Acts of 1934 and the Potato Act of 1935 are likewise exercises of the congressional power to regulate interstate and foreign commerce, and the allotments provided for in these acts are allotments for marketing in the channels of interstate and foreign commerce. In addition, taxes are imposed under the tax power on the marketing of commodities in excess of the allotments. These taxes, like the processing taxes, are excises for revenue-producing purposes and are uniform both geographically and in their incidence upon the class of transactions taxed. Amendments to the Bankhead and Kerr Acts enacted at the last session of Congress make the legislative standards that guide the administration of these laws more explicit.

FOREIGN TRADE AND ITS ALTERNATIVES

In shaping a national farm policy the first duty is to conceive it in the national interest, rather than in the interest of any one group. This does not mean that it should necessarily benefit every citizen and every occupation equally and at once. It must plan first to remove inequalities. As part of our national economic policy, the farm-adjustment program depends for its success on the extent to which it promotes truly national ends. It cannot succeed as a purely occupational enterprise. Farmers are not strong enough numerically to assert their interests in opposition to those of other groups; and if they could, it would not be wise for them to do so. But we should distinguish between real and apparent conflicts. There would be a real conflict if farmers tried to undersupply the towns. There is only an apparent conflict when they urge that farm exports should be promoted by a more liberal import policy.

Certainly, lower tariffs would necessitate urban readjustments but there would be compensations. Lower tariffs would aid all people who purchase a varied bill of goods, including all consumers who are salary or wage earners and all industries except those that are not efficient enough to compete with foreign goods in the American market. Moreover, the adjustments necessary for less efficient industries would not exceed in difficulty or in cost the somewhat different adjustments that will be necessary if agriculture fails to regain its foreign market.

In the economic reorganization now in progress our less efficient industries cannot avoid making readjustments of one kind or another. They will certainly have to abandon their more exposed positions. By forming a united front with agriculture in the foreign-trade problem, urban industry will have better prospects of prosperity in the long run. It may have to fall back temporarily at certain points, but only to prepare for a consolidated advance. Though the initial benefits may go to United States consumers and to our major export producers (both agricultural and industrial), even those engaged in sheltered industries will benefit greatly in the end.

The Historical Trend

By this time the situation, in broad outline, must be familiar to almost everyone, and it should suffice to recall the outstanding features. Our economic life, both agricultural and industrial, has

developed in close relationship with that of other countries, particularly those of western Europe. In the nineteenth century our farm exports to Europe, particularly of cereals, livestock products, and meats, reached tremendous figures. Not counting forest products, they amounted in annual value to no less than $840,000,000 by 1900. There was some decline until the World War broke out, and then the farm export trade increased again. By 1918 it had reached a point 45 percent above the pre-war level, and the quantity of beef, pork, and cereals going to Europe was greater than at the height of the agricultural export trade during the nineties.

During the years immediately preceding the World War, this country's exports largely went not only to pay for our imports, but also to pay interest and principal on capital previously invested by Europeans in American rail, industrial, utility, and public securities. Our farm goods moved abroad easily because, in a sense, we had received payment in advance. During the war period foreign nations withdrew much of the capital which they had invested in the United States and we began lending to them. We became a creditor nation. Our export balance now constituted new foreign loans instead of debt payments to foreign countries. But after 1928 we practically ceased making foreign loans, and that part of our export trade which the loans had helped to maintain fell away. We made short-term loans from 1930 to 1933 which cushioned the falling away of that trade. At no time, of course, did loans finance the bulk of our exports. They financed the export balance. Nevertheless, the effect of our changed foreign lending policy on American exporters, both agricultural and industrial, was important. With foreign markets blocked, farm and factory production for export had to be reduced during these hard years even more than was the case for other production, with rural distress and urban unemployment correspondingly enhanced.

Exports and Imports Interdependent

Permanently to regain any substantial part of our lost export trade, it will be necessary greatly to increase our imports of goods and services. Chiefly the increase must be in goods. There is no other sufficiently large possibility. Acceptance of goods in payment for our exports seems likely to be the only adequate basis for an indefinite time. The alternatives to thus exchanging what we produce above our domestic requirements for foreign goods that we could consume are not attractive. For the most part they would involve a further limitation of farm production with additional unemployment in town and country or a drastic reorganization to produce things we are not well fitted to produce and a permanent lowering of our real standard of living.

Agriculture has suffered from the slump in exports much more than industry. Normally we export a large proportion of many of our most important farm products. In the 1920's the export share of the total farm production averaged about 14 percent annually, and this set the price on about 40 percent of what the farmer sold and materially influenced the prices of the rest. In volume it has since declined to less than 10 percent of farm production, with a much greater percentage decline in dollar value. In the fiscal year

1925 agricultural products made up 48 percent of our total exports. In the fiscal year 1930 the proportion declined to 32 percent. It rose to 42 percent in 1933 but declined to 39 percent in 1934. In the fiscal year 1936 (partly because of the droughts of 1933 and 1934) the agricultural proportion will probably be the lowest on record.

These facts indicate what the collapse of world trade meant to our agriculture, for the exportable surplus of any commodity or group of commodities tends to set the price for the whole supply. This was why Agricultural Adjustment Administration controls and the processing taxes were necessary. The collapse hurt industry too; witness the decline in our total exports: From $5,284,000,000 in the fiscal year 1929 the business dropped to $1,413,000,000 in the fiscal year 1933 and recovered only to $2,008,000,000 in the fiscal year 1934. All over the world the sensational decline of international trade is one of the gravest aspects of the depression. American agriculture suffered disproportionately. Cotton, wheat, tobacco, and livestock enterprises could not be readjusted quickly to a domestic market. The acreage required, at average yields, to supply the export market declined from 84,000,000 acres in the fiscal year 1921 to 39,000,000 acres in the fiscal year 1934. To keep this acreage out of production indefinitely is defeatism.

Probable Consequences of Export Paralysis

Without foreign trade, agriculture will have to continue crop limitation and seek compensation in higher unit prices. It will have to make detailed cooperative adjustments, with inevitable repercussions on nonfarm business. In the fullest sense, therefore, the agricultural problem is a national problem, the burden of which must be nationally shared. That is indisputable. There is room for dispute only as to ways and means, and as to the distribution of the cost. Nonfarm groups must decide whether to take the consequences of denying agriculture its foreign market, or to restore this market to the farmers at the cost of certain readjustments in inefficient industries. Nonfarm interests already know something of the penalties of farm contraction toward a domestic basis, but they fear that the other course, including tariff reform, would mean the contraction of urban industries. They see possible injuries but do not appreciate the compensations. Lower tariffs would create new employment by encouraging exports.

We have negotiated reciprocal trade agreements with some countries—Cuba, Belgium, and Sweden—and we have many other agreements pending. But progress is slow because the country does not yet realize that the penalties of the exclusion policy are greater than any that the opposite program would involve. It imagines that exclusion is the lesser of two evils. An example of the muddy thinking that prevails on this subject is the tendency of city dwellers to blame the Agricultural Adjustment Administration for crop limitation. Actually, the original cause is the country's refusal to allow agriculture to regain its foreign market. We fail to import goods enough to enable foreigners to buy our agricultural products. Lower tariffs could restore this market, and it is unreasonable and unfair to blame the effects of crop limitation on the crop-control machinery rather than on the tariff policy that makes the limitation necessary.

The Industrial Viewpoint

Superficially the case against agriculture's plea for a more liberal import policy is plausible. Some urban industries, like the main branches of agriculture, are on an export basis and do not benefit from the tariff. However, much urban industry depends for its prosperity on the domestic market, which it naturally dislikes to share. Accepting imports for exports would tend to cancel our favorable balance of trade. It would increase the supply of commodities for consumption within the country. The increase, if the transaction were to benefit agriculture, would have to consist largely of nonagricultural commodities and of so-called "noncompetitive items." At first sight, then, the proposal to facilitate our farm export trade by lowering the tariff is a proposal to exchange a surplus of farm products for a surplus of industrial goods, and the manufacturer balks.

Turning our net excess of exports into a net excess of imports will necessitate one of two things, both distasteful to tariff-protected industry. It will involve either increased consumption or reduced production within the country; the first means lower prices, the second reduced employment in certain industries. With no compensation clearly visible, the manufacturer recoils. He prefers the bird in the hand. And who will blame him? Before the import program can make headway with the manufacturer, it is necessary to demonstrate that it will not simply rob Peter to pay Paul; that it is sound national economics and will benefit indirectly even the interests that seem the first to suffer. To do this we have to include all the items, not simply those that show up immediately in industrial balance sheets.

Implications of Our Creditor Position

In the sum total of its trade balances with all countries, if we include the so-called "invisible items" in international transactions, we must expect a creditor country like the United States to develop an unfavorable balance. How this balance shall be composed, the proportion which the visible will bear to important invisible items. depends upon a variety of things, including credit conditions throughout the world. Great Britain in the nineteenth century, for example, held down her unfavorable merchandise balance by accepting foreign securities instead of goods. Not until the World War broke out did she take goods almost exclusively in settlement of her claims abroad. When the United States became a creditor nation, it followed the earlier example of Great Britain, and insisted on the largest possible proportion of certain invisible items in the payments due. Instead of receiving goods and services in return for the things it had exported, it demanded promises to pay—stocks and bonds and other evidences of debt.

This course implied a belief that real, tangible payments would be made eventually. It rested, in other words, on confidence in international credit. As that confidence weakened, it became necessary either to forego export trade or to increase imports of merchandise and services. We can state the principle in another way. As world credit weakens, creditor countries demand their pay sooner. Sooner or later, export trade tends to generate a compensating import trade,

and the only practical question is when to accept it. With interest accruing, the deferred commodity payment increases in physical volume. It is a case of receiving back, with an addition representing accrued interest, the commodity equivalent of what we send away or else of foregoing payment almost entirely. To develop an export trade, without simultaneously preparing for the inevitable return flow of goods and services, is economic idiocy.

For our enormous favorable trade balance during and immediately after the World War, we got promises and some services. Subsequently, for a smaller net export balance, we accepted more gold and took less of goods and promises. Finally we practically eliminated the promises; in other words, we refused any longer to accept foreign securities in payment for our exports. We are still hospitable to gold, but the supply will not last forever. Gold kept coming in during 1934 and 1935 partly because our dollar devaluation had increased the purchasing power of gold and partly because gold came here in a flight from shaky European currencies. This may have prevented our exports from falling lower. How long can it continue? Already the United States has nearly 45 percent of the world's monetary gold supply. More would be useless to us. Yet we have dodged balancing our exports by importing goods. Our excess of exports is disappearing mainly through a decline in the exports.

Essentials of the Dilemma

We approach an impasse. In defense of the exclusion policy—or the refusal to take imports for exports—those who believe they profit by it point to its apparent effect on domestic production and employment. There is no gain whatever and probably a distinct loss because it limits the production of the things we are best fitted to produce. As a means of preventing unemployment, the exclusion policy is futile; for unemployment is not exclusively urban but also rural. Unemployment results quite as surely and in as large a volume from the present paralysis of export trade as from pressure on the prices of sheltered industries. Whatever reduces farm production reduces farm employment, immobilizes farm capital and farm land, breaks down the capital structure of agriculture, reduces farm owners to tenancy and farm tenants to wagedom, and creates a surplus of farm labor which must seek relief. Unemployment is also caused in the handling of farm exports. Refusal to take imports for exports may change the distribution of unemployment; it may pile rural unemployment on top of urban; but it does not reduce the total. Protection to one interest is greater damage to another. There is no ultimate gain even to the protected occupations; for out of wages, interest, and dividends the busy must support the idle. False stimulus to a few industries means greater distress for agriculture and greater need to divert industrial income to farm relief.

As a matter of fact, the exclusion policy actually creates unemployment. By paralyzing export trade, it keeps within the country (or makes it necessary to prevent the production of) a mass of surplus commodities for which the country has no need but which under favorable international trade conditions it could exchange for things it does need. Farm goods do not pass freely into consumption beyond a certain point no matter how much purchasing power may be

available, as consumer requirements are not unlimited. The capacity of the stomach limits food consumption. Consumption of industrial commodities, on the other hand, may in many cases increase indefinitely with purchasing power. To exchange farm surpluses for industrial goods is therefore a direct means of promoting consumption. It changes the surplus into a form in which consumption is not checked by sheer lack of physical need but only when it encounters a shortage or maldistribution of buying power. Conversely, by refusing to exchange unwanted farm surpluses for foreign goods that could be consumed if we had them here, we prolong the surplus difficulty. We postpone the time when it will again be necessary for men to resume work; that is to say, we perpetuate unemployment.

Obstacle to a More Liberal Import Policy

Taking imports to pay for exports should not embarrass a country, since the sale of one thing implies the power to buy another. When the United States sells cotton or wheat abroad it obtains command over an equal value in foreign goods. Why does it hesitate to bring in the goods? Why do many other countries similarly object to receiving imports for exports? The general insistence on one-sided trade, on selling without buying, suggests that there must be some good reason for it. There is. Taking imports for exports does not get rid of surpluses but merely changes their form. Something more than the exchange of dissimilar goods is necessary. Purchasing power must be distributed too. This is the real stumbling block. Reciprocal international trade, with each country's exports approximately balanced by imports, leaves the problem of matching consumption with production essentially unchanged and emphasizes the necessity for internal adjustment. Whether exporting will create purchasing power enough to absorb the equivalent imports depends materially on who gets the purchasing power. To stimulate consumption, purchasing power must be in the hands of those who need or desire goods and services. International trade may increase needs or desires by creating opportunities to satisfy new wants. But if purchasing power is very unevenly distributed it will not create enough new wants accompanied by the power to satisfy them. So, restoration of international trade will not by itself eliminate the problem of the surplus. It requires the support of a domestic policy that maintains a distribution of the national income which will enable many potential buyers to be actual buyers.

Income Redistribution Involved Inevitably

Here, then, is what we must recognize: The redistribution of income is not a proposal but a necessity. In one way or another it results automatically from any of the courses open to us. We cannot avoid it by ceasing to produce for export and by limiting our imports to necessities. That is to cripple agriculture, to make permanent the necessity for costly farm relief, to compel disadvantageous urban adjustments, and to create scarcity. The resulting unemployment involves heavy public expenditures. In such circumstances we first reduce the national income and then redistribute the reduced total to avert disaster.

The other course open to us involves a redistribution of income likewise, but under happier conditions. With production stimulated through international trade, the total national income would increase, and though the increase would have to be distributed so as to increase consumption per capita, the operation would raise the national standard of living. By this means we would be balancing the national consumption with the national production or its equivalent—and on a rising scale.

Foreign Trade Benefits Well Diffused

Agriculture will not monopolize the benefit of a more liberal import policy even in the earlier stages. If we admit foreign goods into the United States, it will provide dollar exchange that other countries can spend. What they buy will depend on many things. Recently, foreign countries have reduced their purchases of farm goods in the United States. They have cut sharply their takings of cotton, diminished somewhat their purchases of tobacco, reduced to a very low level their buying of pork products, and practically ceased buying American wheat. On the other hand, they have increased their purchases of automobiles, radios, farm machinery, and other industrial goods. These differences reflect partly the relative superiorities involved in the different types of production, partly the geographic sources of the foreign buying. As a result of the drought, our ability to compete in the international market for wheat and hog products is temporarily low. In the case of cotton, exchange difficulties are important. Cars, radios, and farm machinery, on the other hand, are going largely to agricultural countries whose tariffs are mainly for revenue; but American agriculture still has most of the natural and technical advantages that helped it formerly. Restored foreign buying power could not fail to stimulate farm exports, provided we have ordinary weather and Agricultural Adjustment Administration production policies are arrived at with common sense. The benefits of restored foreign trade ought to be shared, otherwise the motive for encouraging it and for making the necessary adjustments and temporary sacrifices would not persist. The choice of a liberal foreign-trade policy promises so much general benefit that even those who are involved in difficult readjustments can expect to profit in the long run.

SIGNIFICANCE OF FARM IMPORTS

As farm commodity prices rise from the effects of the recent drought and of the Agricultural Adjustment Administration programs, agriculture moves toward an important decision. It must choose between action calculated to increase and action calculated to decrease its exports. Manifestly, domestic prices above world prices discourage exports and encourage imports. Is the remedy to be found in higher tariffs or embargoes? Farm imports have increased during the last year, and a demand has arisen for their exclusion.

It is certainly possible to exclude foreign commodities from the domestic market; but the action will tend at the same time to keep within the country products that should go out. That the refusal to import makes it more difficult for a country to export is a truism which applies whether the goods kept out are competitive or non-

competitive. Practically, the question to be decided is whether a small gain in the home market is worth a substantial loss in the foreign market.

This country normally imports small amounts of competitive agricultural commodities, including those which it normally exports. Certain areas near the boundaries find it cheaper to pay duty than freight charges from distant points within the United States. Sometimes, too, we have domestic shortages, which imports supply. Again, certain types of products, such as cotton of a particular staple, may not be obtainable within the country.

In exceptional circumstances, such as those created by the drought of 1934, the farm imports may increase. They may include substantial amounts of the goods that we normally export, as well as quantities of products likely always to be in short supply in seasons of crop failure. At such times it may seem that the domestic producer, with his natural desire to make up for his low production by getting higher prices, should have the aid of special tariffs or embargoes. Our imports of grain, the domestic production of which was tremendously reduced in 1934, increased heavily on a percentage basis, but the imports of most other competitive commodities remained below the 10-year average (table 1).

TABLE 1.—*Imports of certain groups of agricultural products*

Group	Unit	10-year average, fiscal years, 1925 to 1934	Fiscal year 1935
Fruits	Short ton	1,496,000	1,371,000
Fruits, excluding bananas	do	103,000	71,000
Vegetable oils	do	405,000	432,000
Oilseeds	do	771,000	706,000
Total		1,176,000	1,138,000
Meats	Pound	82,773,000	81,259,000
Vegetables	do	734,787,000	362,491,000
Wool	do	212,358,000	122,789,000
Dairy products	do	146,433,000	74,697,000
Eggs and egg products	do	17,566,000	6,219,000
Corn	Bushel	1,537,000	20,427,000
Oats	do	494,000	15,614,000
Barley	do	84,000	10,978,000
Wheat	do	[1] 838,000	[1] 5,906,000
		[2] 78,000	[2] 8,146,000
Rye	do	1,204,000	11,230,000
Hay	Short ton	99,000	88,000
Value of total agricultural imports	Dollars	1,660,252,000	970,853,000

[1] Full duty. [2] 4-year average. Wheat unfit for human consumption.

Demand for Exclusion

The increase in grain imports caused a wide-spread demand, among both farmers and nonfarmers, for higher tariffs and even embargoes on these and other farm imports. It is inconsistent, said those who demanded such action, to import goods the production of which we restrict within the United States.

That sounds very logical. Actually, however, the issue is not nearly so clear cut. It would, of course, be absurd to throw the United States wide open to world competition in goods that we can and do produce abundantly and efficiently ourselves. Such action would at any rate be absurd under present circumstances, with agri-

culture overexpanded, with farmers at their wits' end for an adequate market, and with crop-adjustment programs in effect.

No one suggests that we should do that. The reality is quite different. The farm imports now entering the United States are only a trickle, and there is no chance that they can become a flood. On a percentage basis the rise in grain imports looks portentous. In comparison with our domestic grain production the inflow is insignificant. It constitutes a very small fraction indeed of the domestic production. It is estimated that the 1934 drought caused, independently of the Agricultural Adjustment Administration crop adjustments, a decline of more than 2,000,000,000 bushels in our grain production. Our grain imports from July 1, 1934, to June 30, 1935, were less than 3.5 percent of the loss of all grains due to the drought, and only 1.5 percent of our average grain production in the years 1928–32.

During the fiscal year 1935 our wheat imports for domestic consumption (which does not include bonded wheat imports for milling and reexport) were 1.6 percent of our average annual wheat production from 1928 through 1932. Our corn imports during the same period were 0.8 percent of our annual corn production. Normally the United States consumes practically all the corn it produces and builds up a surplus following good years. In a subsequent period of low yields this surplus may disappear quickly, and it may be necessary to import some corn. Small quantities of corn may be imported for use on the Atlantic, Pacific, or Gulf seaboards, even following seasons of normal production in the United States. That the last 2 years of drought have created a situation favorable to corn imports is not surprising; had the Government not greatly reduced livestock numbers last year it would have been necessary to import considerably more corn. Our imports of oats and barley, though relatively larger than our imports of corn and wheat during the fiscal year 1935, were actually quite small. Oat imports were 1.3 percent of the average (1928–32) production. Barley imports were 3.9 percent of the average production; rye imports were 29 percent of the average production.

Imports Entered Over the Tariff Wall

These imports all came in over the regular tariff wall in accordance with the Tariff Act of 1930. Wheat paid a duty of 42 cents a bushel, corn 25 cents, oats 16 cents, barley 20 cents, and rye 15 cents. It is worth noting that the imports were relatively largest in commodities not covered by Agricultural Adjustment Administration programs, as for example, oats, rye, and barley. The drought was exclusively responsible for the diminished production of these crops. Beef imports paid a duty of 6 cents a pound or not less than 20 percent ad valorem for canned beef.

There was no change in the tariff duties except on hay and straw. On these commodities, in response to a petition from livestock producers, the President issued a proclamation, effective August 30, 1934, temporarily removing the tariff, and hay came in duty-free for consumption mostly in drought areas near the Canadian border.

With normal growing weather and larger production in the United States, the imports will decline. With reduced livestock numbers, even a moderate corn crop this year would produce a supply

sufficient for domestic requirements. Points near the seaboard may import small quantities, in preference to getting supplies by rail from the Corn Belt; but the amount will be trifling. Normal yields of wheat, oats, and barley would eliminate the necessity for importing these commodities, though in any years of low yields some foreign shipments may come in.

The logical way to prevent that would be to maintain larger domestic carry-overs. It might be cheaper and more efficient to allow occasional imports, because the irregularity of the high- and low-yielding periods makes an ideal distribution of wheat, oats, and barley very difficult. Small imports of butter should be considered normal from time to time, because our butter production is ordinarily just about enough for our domestic requirements.

No Reason For Alarm

There is consequently not the slightest reason to be alarmed over the recent moderate increase in certain farm imports. Tariff policy should consider not the exceptional but the normal position of the commodities to which it applies. Tariffs are usually not effective on commodities which farmers normally export in large quantities. Such tariffs become effective only when these commodities temporarily shift, through crop failure, to an import basis; and the beneficial effect on prices disappears as the production returns to normal. Meantime, in the periods of shortage, farmers get world prices plus the tariff; they could not do appreciably better by shutting out the imports altogether.

Producers will generally find it more satisfactory, both in production and in fiscal policy, to plan on conditions that are likely to remain fairly stable. Much permanent advantage cannot be derived from frequent tariff readjustments designed to meet temporary and exceptional conditions, mainly because it is impossible in tariff making to keep step with every seasonal change in supply and prices.

Wheat, corn, and rye, for example, might be back on an export basis, and thus be incapable of profiting from tariff protection, almost before new tariff regulations could be put into effect; and the same could happen with other products. With its chief farm products the United States is still heavily on an export basis. Even in 1934, with production tremendously curtailed by drought, it exported more than $650,000,000 worth of cotton, tobacco, meat products, grains and grain preparations, fruits and fruit preparations, and dairy and poultry products (table 2). In framing agricultural tariffs this fact should never be forgotten.

TABLE 2.—*Value of exports for calendar year 1934 and for fiscal year 1935*

[In thousands; i. e. 000 omitted]

	Calendar year 1934 [1]	Fiscal year 1935 [1]		Calendar year 1934 [1]	Fiscal year 1935 [1]
Meat products	$35,169	$33,080	Tobacco, unmanufactured	$125,064	$120,515
Dairy products	5,195	5,270	Cotton, unmanufactured	372,755	333,586
Eggs and egg products	478	513			
Grains and preparations	39,410	31,321	Total	650,188	595,135
Fruits and preparations	72,117	70,850			

[1] Preliminary.

Bad Effects of Prohibitive Farm Tariffs

It may seem that agriculture could profit from high tariffs on export crops in seasons of shortage, and lose nothing in seasons of surplus. That is not so. High tariffs on export crops, besides being useless most of the time, commit agriculture to a high-tariff philosophy, encourage other industries to demand prohibitive tariffs on their goods, and provoke retaliatory action abroad. Thus, without safeguarding agriculture's home market, they damage its foreign market, the basis of which is reciprocal international trade. Agriculture cannot demand a high tariff for itself and a low tariff for urban industry; and yet without tariff adjustments downward it must resign itself to a permanent and progressive loss of exports.

Our farm export trade in 1934, albeit much reduced from the predepression level, was still essential. Though crippled by special foreign tariffs, quotas, and exchange controls, it provided an indispensable safety valve. It is far more important to work for the removal of the handicaps than to employ their equivalent ourselves in an effort to give the American farmer the whole American market.

Normally the farmer has practically that whole domestic market, anyway; for him to give up the possibilities of regaining the foreign market for the sake of the trifling additional advantage of making the domestic monopoly absolute would be extremely poor business. In 1934 our imports of commodities competitive with the cotton, tobacco, meat products, and grains which we exported, including $24,000,000 of practically noncompetitive bananas, amounted to only $126,000,000, as compared with the $650,000,000 worth of exports (table 3). Prohibitive tariffs would tend to sacrifice the larger to the smaller item.

TABLE 3.—*Value of imports for calendar year 1934 and fiscal year 1935*

[In thousands; i. e., 000 omitted]

	Calendar year 1934 [1]	Fiscal year 1935 [1]		Calendar year 1934 [1]	Fiscal year 1935 [1]
Meat products	$12,812	$16,650	Tobacco, unmanufactured	$24,932	$23,913
Dairy products	10,864	14,289	Cotton, unmanufactured	9,456	7,870
Eggs and egg products	443	1,057			
Grains and preparations	33,212	59,897	Total	126,442	161,818
Fruits and preparations	[2] 34,723	[2] 38,142			
			Bananas	24,104	26,594

[1] Preliminary.
[2] Including bananas.

Reasonable tariff protection for agriculture, such as it has now, is necessary and desirable, but it does not follow that increased protection would give commensurate benefits, even on the few commodities which such protection could temporarily affect. The imports it would exclude are comparatively small, and their exclusion would have very little effect on prices in this country. In some cases higher tariffs or embargoes might cause an advance of prices; but whether such advances would produce more income for the farmers is another question.

Probably they would not. Extreme limitation of supply, below the basic needs of domestic consumers, whether accomplished through acreage control or through tariffs and embargoes, is neither a sure nor a justifiable means of increasing net farm income. Such action often hurts the consumer without helping the producer, because as prices rise consumption falls. At a given point, decrease in consumption can offset the advantage of higher prices. In the first months of 1935, high prices due to last year's drought caused an increase in our imports of butter; but the high prices had still another undesired effect. They caused a sharp drop in butter consumption, which in February was 24 percent less than in February 1934. Farm income depends on the volume of sales as well as on the unit prices received, and price gains brought about through a rigid exclusion of imports would not produce more income automatically.

It is important to remember also that price gains produced by special tariffs would not last because they would overstimulate domestic production. Agricultural Adjustment Administration controls, since they depend essentially on the farmers' wishes, would not be a sufficient safeguard. With imports totally excluded, farmers would not wait for normal growing conditions to supply the demand. They would anticipate matters and produce new surpluses.

Recovery from the drought will cause farm imports to decline without the aid of higher tariffs, and this natural decline, reflecting more adequate domestic production, will increase the producers' income and inflict no hardship on the consumer.

DUAL-PRICE SYSTEMS

There are proposals to establish a dual-price level for farm commodities by means of export subsidies, rather than by the means provided in the Agricultural Adjustment Act. The Agricultural Adjustment Administration method maintains dual prices for the basic commodities subject to processing taxes, and permits dual-price operations in marketing agreements. Domestic consumers pay the processing taxes, while foreigners do not. The result is that the taxed commodities cost more within the country than outside it. But the Agricultural Adjustment Administration method tends to narrow the spread between prices to consumers at home and prices to consumers abroad, because it promotes an adjustment of supplies to market requirements, and works toward a situation in which the processing taxes may be reduced. The proposed alternatives would have the opposite effect. Export subsidies without production control would overstimulate production and force world prices down. The subsidies would have to be constantly increased, so as to move out an ever-increasing export surplus. Otherwise domestic prices too would fall.

Not all the advocates of export subsidies favor the abandonment of production control, but the proposal leads naturally in that direction. Temporarily it would raise domestic prices to all producers, without regard to their participation or nonparticipation in crop control. Thus it would weaken the incentive to adjust output to the real demand. Some proponents of the export subsidy urge

frankly that production control should be dropped. They hold that any quantity of farm products can be sold in world markets at some price and that no matter how low world prices may go the farmer can be assured of parity on the domestically consumed part of his crop. It is important, they believe, to retain the foreign market at almost any price.

Two such plans, the McNary-Haugen plan and the export debenture, were advocated widely in the decade of the twenties. Both contemplated a two-price system—one price level for American products sold abroad and a higher price level for the same commodities at home. Under the McNary-Haugen plan export surpluses would have been segregated from domestic supplies and sold abroad for any price obtainable. The domestic supplies, thus brought to the point of shortage, would have commanded a price higher than the world price by the amount of the tariff. Out of this enhanced domestic price, each grower would have contributed an equalization fee to cover the loss on the exports. Under the export-debenture plan exports would have been encouraged by a subsidy derived from tariff revenue; and this bounty on exports would have raised the domestic price above the world price. Under either plan there would have been danger of stimulating production greatly, and also of causing foreign countries to adopt retaliatory measures. The lowering of world prices would certainly have aroused objections abroad.

Prior to the world crisis of 1929 these difficulties did not appear to be insuperable. Some economists believed foreign countries would be glad to get our farm goods at bargain prices and would not regard the " dumping " involved as seriously objectionable. After the crisis this opinion had to be revised. It was no longer a question so much of the desirability as of the practicability of selling unlimited quantities of farm products abroad. Prices of cotton, wheat, and other products were extremely low in 1932; but the supplies could not be exported freely. With wheat for the crop year 1932–33 averaging only 37.9 cents a bushel on American farms, the exports were only 41,211,000 bushels, or less than one-third of the pre-war and predepression normal. Hogs in 1932 were down to $2.73 a hundred pounds; yet exports of pork were only 1.7 percent of the total production, as compared with 9.8 percent from 1920 to 1924. Cotton exports increased; but cotton prices were so low that the gross return to producers was the smallest since 1901, and the increased export volume went to increase the stocks rather than the consumption of American cotton abroad. The result was that our cotton exports declined in subsequent years.

Expense of Forcing Exports

Exports could doubtless have been increased by very large subsidies even during the worst years of the depression; but the cost to the United States would have been tremendous. With production unchecked, such subsidies would have involved presenting to foreigners at less than its value an ever-increasing proportion of the agricultural output. One result would have been a constant widening of the spread between domestic and world prices. Moreover, the plan would have stimulated manufacturing abroad and discouraged it at home, because foreigners would have been able to undersell Americans in

world markets with goods processed from American raw materials. Any action that keeps American prices above world prices has this effect to some extent; and a program that tends progressively to increase the differential is profoundly objectionable.

Furthermore, one country after another adopted antidumping laws and trade restrictions of various kinds. The world gave clear notice that it would interpose effective barriers to dumping programs. There was every reason to expect, moreover, that exporting countries whose agricultural products compete with ours in the world market would try to counteract the effect of any export-bounty system which the United States might adopt. In the worst period of the depression it is probable that the adoption of the McNary-Haugen plan or the export-debenture plan would have prevented and not stimulated exports. Either plan would have prompted foreign countries to increase their trade restrictions.

Under the farm-adjustment program finally adopted the United States gave foreign countries no ground for complaint on the score of dumping. It served to raise rather than to depress world prices. True, the plan raised prices to domestic consumers more than it did to foreign consumers; but the supply adjustments strengthened the entire market, yet without sacrificing the foreign demand. American producers continued to offer all the tobacco and cotton that the foreign market would take; and it was the drought, rather than the Agricultural Adjustment Administration adjustments, which eventually reduced unduly the offerings of wheat and pork. In short, the Agricultural Adjustment Administration method did precisely the opposite of what a straight export bounty would have done, in that it served to regulate production in accordance with the capacity of the export market. A shift now to the export-subsidy plan would have manifest disadvantages. Exports can be increased, moreover, under the Agricultural Adjustment Administration programs whenever the opportunity offers. The processing-tax method, with its power to establish a differential between domestic and world prices, provides the necessary means.

Limited Provision for Export Subsidies

Amendments to the Agricultural Adjustment Act, which were approved August 4, 1935, make limited provision for export subsidies as an accessory to the present method. Section 32 of the amendments appropriates a fund for: (1) Subsidies for the encouragement of exports, including among other things direct export subsidies; (2) subsidies to encourage the domestic consumption of agricultural commodities by diverting them from the normal channels of trade; and (3) expenditures to finance the regulation of production. For any one fiscal year the fund is limited to 30 percent of the customs revenue during the preceding calendar year. For the present fiscal year the amount available is $92,000,000. But even if the whole of this amount were spent on export subsidies, it would not cover more than a fraction of our agricultural exports.

Clearly Congress did not intend that export subsidies should be adopted on a large scale. It will be necessary, in order to make the best use of these provisions, to confine export subsidies to cases in which such subsidies have a net advantage over all other methods.

Also, it will be necessary to avoid subsidies that might tend to increase production for export significantly and give cause for foreign retaliation. In specific instances, as in the sale of wheat in 1934 through the North Pacific Emergency Export Association, subsidized exports may be desirable and feasible; but each case must be judged on its own merits. The course of action in respect to any commodity must fit the circumstances.

FARM INCOME

Farm-income data, though not a perfect measure of farm welfare, are the best we have. They reflect the distribution of farm earnings by commodities and regions, the relationship between farm expenditures and farm returns, and the proportion which the farm income bears to the national income. The statistics do not measure all these relationships exactly. For example, the gross farm income includes the value, at farm prices, of home-grown products used by the farm family. This portion of the farm income is not the equivalent of money available for spending. The imputed money value of the home-grown products consumed on the farm may change, with no corresponding change in the benefits derived therefrom. Similarly, the money income of agriculture may change as a result of changes in the buying power of the dollar, in a manner and to an extent which do not precisely measure corresponding real changes in farm prosperity. It is desirable to bear these limitations in mind and to remember that fluctuations in farm income merely approximate the changes that take place in the production and distribution of wealth.

It is too early as yet to estimate, except very roughly, the return to farmers from their production in 1935. Marketing of the crops will not be finished until well along in 1936. Present indications are that the farmers' gross income from the year's production, and from rental and benefit payments, will be approximately $7,800,000,000. This total may be compared with $7,300,000,000 gross income from the production of 1934, and $5,337,000,000 in 1932, when the depression was at its worst. In 1929, in which year the gross farm income was at the highest level since 1920, the total was nearly $12,000,000,000. While the gross farm income for 1935 is approximately one-third lower than that of 1929, the prices paid by farmers for goods and services are about one-fifth lower. The 1935 gross farm income will have about four-fifths of the purchasing power that the gross farm income of 1929 had. Farm population has increased in the meantime about 10 percent, but some of the increase has been supported on relief. It would not be quite true, therefore, to say that this year's farm earnings must be spread over 10 percent more people than the earnings of 1929.

Naturally, the marked rise in the gross farm income since 1932 has been distributed unequally by commodities and regions. These crop and regional differences appear best in the statistics of cash income from marketings and rental and benefit payments, which, unlike the gross-income statistics, reflect current receipts. Cash income includes only current receipts, regardless of when the products were produced, and regardless of the time when the recipients of rental and benefit payments performed their contractual obligations. It consti-

tutes the money return from agricultural operations, exclusive of the imputed value of the home-grown products used on the farms. Available cash-income data furnish regional comparisons up to June 30, 1935. It will be convenient to cite only percentage gains so as to avoid confusing the cash-income with the gross-income figures.

For the United States as a whole the cash farm income from marketings plus rental and benefit payments was 48 percent greater in 1934 than in 1932. In the South Atlantic region the increase was 81 percent; in the North Atlantic region it was 22 percent. The greatest advances occurred in the South Atlantic and South Central regions, which suffered the greatest decline in the 1929–32 collapse. From 1932 to 1934 the producers of cotton and tobacco benefited more than most other farm groups from the devaluation of the dollar and perhaps more also from the agricultural adjustment programs. Cotton and tobacco prices are determined to a large extent in the foreign market, and the depreciation of the dollar in foreign exchange raised these prices materially. Drought reduced the income from crops in the central regions in 1934, but heavy marketings increased the income from livestock. The period 1932–34 witnessed the restoration of a more normal balance among different crops; the years 1934 and 1935 brought new distortions which will influence the regional distribution of farm income for the next year or two.

Regional Distribution of the Gains

For the country as a whole the cash income from marketings in the first half of 1935 was 13 percent higher than in the first half of 1934. The increase was greatest in the East North Central and the West North Central regions, and resulted principally from higher prices for livestock and grains. Improved conditions in 1935 tended to make the regional distribution of the cash income more normal in the second half of the year.

The North Atlantic States normally get 10 percent of the national gross farm income. In the years 1932, 1933, and 1934 they received 12.6, 11.8, and 10.9 percent, respectively. Low returns from potatoes reduced the percentage in 1934. The East North Central States, which normally have 17.6 percent of the total farm income, received practically that share in 1932 and 1934, and 16.6 percent in 1933, when the grain crops were small. The normal share of the West North Central States is 25 percent. They received 22.3 percent in 1932, 23 percent in 1933, and 21.9 percent in 1934, the year of the great drought. The South Atlantic States, whose normal share is 11.7 percent, got about 13 percent in 1933 and 1934. The South Central States received 22.6 percent of the total in 1933 and 20.8 percent in 1934, as compared with 22.2 percent in the predepression years. The Western States received about 16 percent of the total in 1933 and 1934, as compared with 13.5 percent in the predepression years. The West North Central States and the South Central States felt the depression more than the North Atlantic and the Western States.

Recovery in 1933 tended to restore the normal balance, but the drought of 1934 retarded progress in that direction. Advantages of the Agricultural Adjustment Administration programs in 1933 and 1934 were not confined to the regions in which farmers received

rental and benefit payments. Indirect benefits resulted from the industrial activity which the programs stimulated. It is significant, for example, that car-lot shipments of manufactured goods from 16 Northeastern industrial States for use primarily by farmers in 10 Southeastern States showed an increase of 75.1 percent in the first year after the farm-adjustment programs and other recovery measures were started. The increased employment and increased factory pay rolls gave farmers better markets in nearby industrial centers. This was an important factor in the relative advantage of the North Atlantic States, as compared with the position of some of the other regions.

The Purchasing Power of Farm Commodities

In studying the significance of the gross farm income, a basic consideration is the relationship of farm prices to nonfarm prices. An increase in the income available to the operator and his family may be entirely offset by advancing prices for nonagricultural goods and services. Since 1933, however, the prices received by farmers for their products have risen more than the prices of the things that farmers usually buy. It will be recalled that in 1933 the general level of farm-commodity prices was only 55 percent of the pre-war (August 1909–July 1914) average; whereas the prices of the things that farmers buy had dropped only to 100 percent of the pre-war average. In other words, farm commodities per unit had then only 55 percent of their pre-war purchasing power. Grain prices early in 1933 averaged only one-third of their pre-war level.

In the 2 years ended February 1935 the general level of farm prices more than doubled; since then the trend has been slightly downward. The greatest advances since 1933 have been in grain, cotton, and livestock prices. In the second half of 1933 and in the first half of 1934 the prices of the things that farmers buy rose rapidly. The result, of course, was partly to offset the advantage to agriculture of the rise in farm prices. In the last year or so the prices of commodities purchased by farmers have remained practically unchanged at around 126 percent of the pre-war level. In September 1935, when the farm-price index was 107, the purchasing power per unit of farm products for articles farmers buy was 86 percent of the pre-war average.

Another factor in determining the importance of the gross farm income is the level of production costs in agriculture. In the last 2 years farm costs of production have increased less than the gross farm income. This is a typical phenomenon in periods of recovery from depression and tends to compensate for the opposite condition which prevails on the down-turn. Changes in production costs lag behind changes in prices, with the result that in a period of recovery the margin of income over expenditures increases. Thus in 1934 the gross income of agriculture was nearly $2,000,000,000 more than in 1932, whereas the total expenditures for production were only about $320,000,000 greater. Moreover, the principal increase in production expenditures was in capital items such as machinery, buildings, and repairs, which are in the nature of permanent improvements. However, farmers did not provide fully for the depreciation of their machinery and buildings.

Valuation of Farm Assets

Still another significant factor in the welfare of agriculture is the change in the valuation of farmers' assets. This change may result from changing prices for farm land and livestock and from increases or decreases in farm inventories. From 1930 to 1933 the value of farm property in the United States declined nearly $22,000,000,000. It has recovered moderately in the last 2 years but is still nearly $20,000,000,000 less than in 1930. On a reduced property valuation, a given monetary income will show a higher rate of return, and vice versa. On the relatively low valuation in 1934 the return to farm operators for their capital and management was estimated at 4.4 percent. Had farm-property valuations remained unchanged from 1929, the return to farmers for their capital and management would have amounted to only 2.6 percent in 1934.

After paying the current expenses of production, making allowances for the depreciation of their buildings and equipment, deducting rent to landlords, and deducting interest, taxes, and the wages of hired labor, the income available to farm operators for labor, capital, and management, from the production of 1934 was $3,468,000,000 as compared with $2,683,000,000 in 1933 and $1,492,000,000 in 1932. The figures given above may be compared with $5,669,000,000 for 1929, the last predepression year. These figures make no allowances for delinquencies in interest and tax payments, which in recent years have increased markedly. In 1934, however, the farmers paid considerable amounts in deferred taxes and interest; moreover, taxes continued to decline, and the amount of interest due was somewhat lower.

The gross farm income depends on the volume as well as on the prices of farm commodities, but the relationship is complex. Sometimes the maintenance of a satisfactory farm income requires a decrease in production, especially in years when surpluses accumulate; again it may require an increase, as in years following crop failures. From 1930 to 1931, in which period the prices of farm commodities dropped sharply, our farm production declined scarcely at all. Farm income in these years apparently declined somewhat less than income in other industries, because the large volume of production partly compensated for the low prices. Eventually, however, farmers became unable to offset low prices with large volume. They found themselves compelled to support their prices and incomes by reducing their output pending the disposal of accumulated stocks. Crop adjustments under the Agricultural Adjustment Administration helped to produce a notable recovery both in farm prices and in farm income in 1933 and 1934. In both years drought conditions and the revaluation of the dollar contributed to the upward price movement. The drought, however, reduced production below the most desirable level, and farm prices rose proportionately more than farm income. We now have before us the task of getting back to a more normal production of livestock and of working out the proper balance between adequate supplies for urban consumers and adequate returns to producers. Farm production will have to be increased substantially above the 1934 level in order to maintain farm income at the level established in that year and in 1935. In 1934 the volume of the farm output was 91 percent of the average for the period

1924–29. The current year's volume is now estimated at 89. The decline was primarily due to a reduction in livestock. The volume of crop production available for sale and consumption on the farm increased from 68 to 83 percent of the 1924–29 average, whereas livestock production declined from 110 to 93 percent of the same base.

AGRICULTURAL CREDIT

The increase in farm income in each year since 1932, together with measures that have been taken to reduce farmers' debt burdens, have resulted in continued improvement in agricultural-credit conditions. While the debt situation of many farmers, particularly in areas which suffered from drought, is still unsatisfactory, higher prices for farm commodities have brought farm income into better alinement with fixed charges such as interest and taxes.

Additional reductions in interest payments have been effected under the refinancing program of the Farm Credit Administration. During the year ended May 31, 1935, new farm-mortgage loans of the Federal land banks and of the Land Bank Commissioner amounted to $928,000,000, bringing the volume of new loans, since the beginning of 1933, to a total of $1,739,000,000. These loans, which have been used primarily for refinancing other indebtedness carrying a higher rate of interest, have thus been the means of effecting an appreciable reduction in farmers' annual interest payments. As a result of recent legislation, interest rates on Federal land-bank loans, which had been temporarily reduced to 4½ percent for a 5-year period, are further reduced for a period of 3 years beginning July 1, 1935. In the first year the annual interest rate will be 3½ percent and in the 2 following years 4 percent.

The Federal land banks are now making new mortgage loans at an annual interest rate of 4 percent, the lowest rate in the history of the system. Loans from other agencies, while in relatively small volume, have also tended toward lower interest rates. These reductions, which appear to indicate a permanent lowering in the average interest rate charged on farm mortgages, may be expected, eventually, to be recapitalized, in part, in relatively higher land values. To the extent that this recapitalization takes place, the equity of farm owners will be further enhanced. Of course, so far as new farmers are concerned, the higher land values thus resulting will tend to offset the advantage of lower interest rates.

Farm taxes, which have been declining since 1929, declined further in 1934, the average tax per acre in that year being about 5 percent lower than in 1933. The average reduction from 1929 to 1934 amounts to 37 percent, a reduction which has appreciably lessened the burden of the total fixed charges on farm property. Decreases in real-estate taxes, however, have been offset in part, in some States, by other forms of taxation, particularly by sales taxes.

Improvement in the facilities for providing short- and intermediate-term credit for farmers has been characterized by the further increase in deposits of country banks and in the loan operations of the production credit associations. In 20 of the leading agricultural States, net demand deposits of member banks of the Federal Reserve System, located in places of less than 15,000 population, increased 23 percent in the year ended June 1935. In the latter month

such deposits, at a level equal to 80 percent of their 1923–25 monthly average, were 85 percent higher than the low point reached in April 1933.

FARM LAND VALUES

Reflecting the continued agricultural recovery, farm real-estate values increased during the year ended March 1, 1935, for the second successive year. The improving market for farm land brought with it certain definite advantages to agriculture. It increased the equities of farm owners, made loan companies more willing to finance sales, encouraged tenants to consider buying their farms, and gave members of the older generation a chance to step out of active farming with less sacrifice than in recent years. The up trend resulted mainly from the improvement achieved in farm earning power and from aid extended by the Farm Credit Administration and by private lending agencies in the refinancing of mortgage debt.

Farm land values tend normally to vary with farm earning power, current and prospective, and the prevailing recovery follows a long period during which the curve was downward. This Department's index of the average value per acre of farm real estate rose, in the 12-month period ended March 1, 1935, from 76 to 79 percent of the pre-war level. Creditor agencies with farms for sale in some cases raised their asking prices, and the general tone of the farm real-estate market improved materially. The rise in valuations brought welcome relief to farmers who had seen their life savings approach the vanishing point. The increases in value were distributed throughout most of the principal farming sections, and evidenced the broad extent to which farm earnings had improved in the preceding 2 years. The greatest advances relative to a year ago took place in the Southern States. There were substantial gains in the East North Central States and in Iowa. In the western part of the Middle West and in certain areas of the Southwest, however, the drought of 1934 influenced valuations adversely.

Changes of ownership of farm real estate showed encouraging trends during the year. Fewer forced sales resulted from debt difficulties or from failure or inability to pay taxes. Forced transfers associated with debt declined from an estimated frequency of 28 to 21 farms per thousand of all farms. The decreases were general and occurred in nearly all the States. Changes of ownership resulting from failure to pay taxes involved 7.3 farms per thousand of all farms, as compared with 11.1 in the previous year. Voluntary sales and trades were estimated at 19.4 farms per thousand of all farms, as compared with 17.8 in the preceding year. Federal land banks reported increased sales, higher prices, and a larger proportion of the selling price received in cash payments.

Dangers of Overvaluation

The returning market for farm real estate carries with it the reminder that rising farm realty values in the past have not always been without untoward effects on agriculture. The agricultural difficulties of the post-war depressions would have been far less serious had not farm real estate been greatly overvalued in the preceding boom. Prior to 1920 the belief appeared to be wide-spread that farm earning power would always increase; and in some areas more than

half the current selling price of farm land reflected the expectation of such a continued up trend in farm earnings. What happened may be illustrated by the situation in an important Middle Western State. In this State at the beginning of the century, the ratio of net rent to farm real-estate values was about 6 to 7 percent, but it dropped rapidly and by 1920 was about 3 percent. Farmers were borrowing money at 5 or 6 percent to invest in farm real estate valued so as to yield only 3 percent on the investment.

In the crash after 1920 net cash rents soon reached relatively stable levels, while farm valuations continued to decline. But farmers who had contracted to buy land at high valuations did not get relief. On the contrary, they had to reduce their standards of living to the limit in order to meet the interest and tax payments required by their fixed obligations. The ensuing tragedy of foreclosure and loss of homes should serve as a warning against the development of a similar situation in the future.

The farm-adjustment programs, the relief extended to farmers through the Farm Credit Administration, and the progress of general economic recovery have produced a substantial increase in net farm earnings. It should be possible to preserve these gains; but with the total market for farm products restricted as it is by international trade barriers, the achievements of the last few years do not justify extravagant capitalizations of farm income.

In the most favorable circumstances it is wise to keep valuations conservative. Farmers as a group cannot benefit in the long run by allowing an excessive proportion of their earnings to be absorbed in land charges. It is imperative to bear constantly in mind the fact that land charges come out of farm earnings and that speculation in farm land values accentuates booms and intensifies the ensuing depressions. It multiplies the difficulties of men who want to buy farms for actual farming.

Interest Rates and Valuations

Another important development has occurred. Lending agencies, including the Farm Credit Administration, have reduced the rate of interest paid by farmers on long-term indebtedness, thereby reducing the proportion of the farm income required for fixed obligations and increasing the share available for living. The benefit to the debtors is obvious. But if the reduced interest rates are capitalized into higher land values, those who buy and borrow in the future at similar rates will not benefit materially, and the advantage of low-cost financing will be largely lost. With higher valuations and higher loans, interest costs in relation to farm income will not be much changed from what they were before the reduction in interest rates, and there will be more indebtedness to retire.

It is to be hoped that farmers generally will take advantage of the opportunity to raise their living standards and will not capitalize their increased incomes into real estate prices beyond a reasonable level.

RURAL-URBAN BALANCE

That economic recovery requires a good working balance between agriculture and industry, between country and town, is a proposition that looks simple but is really complex. No one can object to balance

as a general principle; for balance is only another name for adjustment, without which nothing can live. Agriculture is a living organism whose life depends, like that of all other living things, on an equality between the inner strength and the outer pressure—on a favorable relationship between the income and the outgo, between the waste and the renewal, between the breaking-down and the building-up. All that goes without saying. Agriculture can prosper only in a balanced relationship with what is external to it, and a good balance for agriculture is necessarily a good balance also for nonagricultural business. But when we drop from the general to the particular and try to specify the form and character of the desired good working balance, we enter difficult ground. What is a good balance between agriculture and the rest of the economic system?

The Agricultural Adjustment Act, as amended in August 1935, makes parity prices for farm commodities an essential factor. Parity prices it defines as prices that will give farm products exchange value, in terms of commodities bought (plus interest and tax payments per acre in most cases), equal to that which they had before the World War. There is more, however, to good rural-urban balance than simply parity prices. That Congress recognized this may be inferred from the act, which requires action calculated to establish and also to maintain fair exchange value for agricultural goods, without injustice to the consumer. Parity prices established on a very high level, through excessive reductions in the farm output, would not last. Such prices could be attained but not maintained. Parity prices must harmonize with increasing consumption if they are to endure. Farm prosperity depends greatly on several factors besides the relationship between farm and nonfarm prices—notably on the volume and the cost of production and on the distribution of purchasing power among consumers. In judging the progress we have made toward parity prices, we must not forget the importance of permanence.

Considered merely from the standpoint of price relationships, the agricultural situation seemed fairly good in 1935. In September the index of prices received by farmers was 107 percent of the pre-war (August 1909 to July 1914) average, as compared with 103 in September 1934 and 55 in March 1933. The March 1933 point was the lowest on record. This gain, in 2 years, of nearly 100 percent, exclusive of benefit payments, brought the purchasing power of farm commodities to about 84 percent of parity. With benefit payments added, the income from basic farm commodities was not far from the price-parity goal. For 14 of the basic commodities named in the Agricultural Adjustment Act the index number in September 1935 was 110 percent of the pre-war level, as compared with 107 for all farm products. On a cursory glance these price statistics may suggest that agriculture had approximately reached its goal and had achieved a good working balance with the rest of the community.

Such was not the case, as we may infer from the conditions that produced the apparently satisfactory price relationships. Prominent among them, of course, was the 1934 drought. Between 1932 and 1934 our farm production, as indicated in marketings, dropped as a whole only 6 percent. In itself this moderate reduction caused no hardship to consumers. (Farm-commodity prices throughout 1934 averaged 10

percent below the pre-war level.) Yet it gave agriculture a considerable gain in net income. Had the reduction stopped at 6 percent, it would have been all to the good; but the drought, coming on top of the Agricultural Adjustment Administration programs, carried the output of some crops far below the level desired, reduced livestock inventories greatly, and menaced production prospects for 1935.

Parity Prices and Parity Incomes

In consequence, farm-commodity prices advanced in the late months of 1934 and the early months of 1935, without a proportionate increase in farm returns. Moreover, the moderate income gains that did result went unequally to different farming regions, those benefiting most that had suffered least from the drought. It is not desirable to have parity prices for agriculture through the temporary effects of crop failure, for the double reason that such prices do not give farmers generally more income and do not promise to last. Moreover, parity prices realized suddenly from the action of the weather bear on consumers more hardly than would parity prices achieved gradually on a basis of expanding consumer buying power. The return of parity prices for many crops does not prove, in the existing circumstances, that the farm depression is definitely over.

As the statistics previously cited indicate, the moderate drop that took place in our farm production between 1932 and 1934 benefited the farmers substantially; but the sharp decline that resulted from the 1934 drought will not by any means increase the benefit proportionately. Beyond a certain point, price gains at the expense of sales involve a loss of income. Parity prices will not return parity incomes if the volume of production decreases excessively; and in estimating the effects of the drought on production it is necessary to consider not merely current marketings but the extent to which the calamity impaired farm production capacity. Its effects on foundation herds of livestock and on feed resources in both grains and grasses will be felt for several years. Meantime, farmers will set in motion production trends that may eventually, despite the Agricultural Adjustment Administration controls, overshoot the mark again and cause another cycle of overproduction. Just now farmers have a lively consciousness of the fact that less and less production does not give more and more income.

It is highly significant that while farm prices advanced 100 percent between March 1933 and March 1935, cash farm income for these months increased only 50 percent. It is true that cash income during the first 6 months of 1935, despite reduced marketings, was larger than in the corresponding period of 1934, but the gain in the income was proportionately much less than the decline in sales. In the long run the farm income depends on the buying power of consumers. After crop failures, consumers may pay as much for food products as they did before and receive less. But the end result, which not even the strongest measures can prevent, is renewed impetus to farm production, both at home and abroad. Experience shows that on an average, with livestock as with crops, the best net return to agriculture comes not from high prices engendered by crop failure but from a normal balance between production and consumer requirements.

Adequate Production Essential

The full year 1935 will furnish a convincing demonstration that the best production policy for agriculture is adequate production for the available market. Crop reduction has reached the point of diminishing returns. The true measure of farm prosperity is the farm income rather than merely the relationship of farm prices to other prices. Scarcity conditions can raise prices almost indefinitely but not incomes. By reducing acreage and livestock breeding greatly, the farmers could raise their prices still more in relation to other prices, but they would penalize consumers, cause a big drop in the consumption of farm products, and stimulate farm competition. Parity prices are not an end but a means. They are necessary, but they are not all that is necessary to establish a good rural-urban balance. Farm income is a better criterion.

The Farm Share of the National Income

That the farm share of the national income is still much below what it should be is evident. From 1910 to 1914, when the farm population was about 25 percent of our total population, agriculture's share of the national income averaged 17.3 percent. In 1932 the farm share averaged only 7.5 percent. Since then it has increased moderately; in 1933 the percentage was 9.9, and in 1934 it was 10.2. But for decades before 1929 the farm income averaged a little more than half the percentage that the farm population constituted of the total population. On the historic basis, the farm share should now be from 13 to 14 percent. True, the long-time trend does not surely indicate the relationship that should always prevail, because the conditions and the technology of agriculture change continually. Moreover, our present farm population, which this year reached a new all-time peak, includes large numbers who are not really necessary to farm production. The problem is to discover how the farm income may be increased so that it will stay increased for all the people who should be on farms.

Our farm population as of January 1, 1935, according to an estimate made by this Department, was the largest in the Nation's history. It was 32,779,000, an increase of 270,000 over the estimate for a year earlier. The increase resulted essentially from the excess of births over deaths on farms. But these figures do not indicate what should be the farm share of the national income because the distribution of population between town and country in 1934 was unstable. The movement of population to and the movement from farms, which is always large, in recent years has shown marked fluctuations. In 1934 more people moved from the country to the town than from the town to the country; for the first time since 1929 there was a net cityward migration, as there had been for a decade prior to the depression. It is estimated that 994,000 persons moved from farms to cities, towns, and villages in 1934, while 783,000 persons moved to farms from the urban centers. Many of the people who went to the farms between 1930 and 1934, however, found only refuge and not work there; they did not add permanently to the gainfully occupied farm population. Our farm population will have to be stabilized under more normal conditions before we can

draw deductions from it as to the proportion of the national income that should go to agriculture.

The Criterion for the Agricultural Share

Since parity prices are not a sufficient test of what constitutes a permanently good rural-urban balance, it may seem necessary to find some other definite basis for determining what share of the national income should go to agriculture. For obvious reasons, it is impossible to set a definite percentage. Suppose the farmers were to force up their prices through scarcity until their income rose to 14 or 15 percent of the national total. Whether or not they could keep the gain would depend on many things, notably on industrial conditions. With continued heavy unemployment in the cities, large returns in agriculture would attract capital and labor into farming, and farm surpluses would reappear. Consumers would rebel against high prices, and the farm share of the national income would decline again. Lifted above the rest of the economic community, agriculture would come under heavy fire from all sides, and a rigid control of agriculture would be necessary to prevent a new disaster.

It is possible, nevertheless, to lay down a principle, if not a percentage, for regulating the farm share of the national income. Sound projects for increasing that share must not hurt other interests and must have enduring elements. Before agriculture can get and keep an increased share, the national income must be increased. The national income depends, of course, on the national production on farms and in factories; it is the country's total command of goods and services. As the total increases, the share going to agriculture may rise without cutting into the amounts available to industry and labor. This may happen with industry and labor receiving more than previously. Amicably to divide an increase in the national income, on principles consistent with social justice, is quite different from quarreling over a decrease produced through scarcity. With production rising on farms and in factories, agriculture could get a larger share of an increased national income without any hardship to other economic groups. A fair return for agriculture would harmonize with general economic progress.

An Increasing Share of an Increasing Total

Fundamentally, the problem is to give agriculture its due share of the national income through an approach to abundance rather than through an approach to scarcity. This necessitates an increase in both farm production and factory production but at different rates. Agriculture has begun to plan for an increased output. But the result, unless urban industry, too, increases its output, will be lower relative farm prices and possibly a further decline in the farm share of the national income, if not also in the absolute income of agriculture. Agriculture cannot achieve its goal without the cooperation of industry. It must get industry to agree that parity income for agriculture should come about, not on an extremely high price level through competitive scarcity but on a lower level consistent with increased production and consumption. Such a balance would harmonize with progress, with a rising standard of living in both town and country and with a just diffusion of the resulting benefits. It

is vital, in redistributing the national income for the ends of social justice, not to jeopardize the amount. Agriculture may fairly ask an increasing share of an increasing total income but not an increasing share of a diminishing total.

As we exhaust the power of crop limitation to advance the farmers' cause, we must emphasize the importance of better reciprocal adjustments between country and town. Under certain conditions it is legitimate and necessary for both agriculture and urban industry to reduce production. Urban industry, however, has done so much more than agriculture. Nonfarm production in 1934 was 42 percent below the 1929 level, whereas farm production was only 15 percent below its 1929 level. The price situation was just the opposite. Industrial prices averaged only 14 percent lower than in 1929, whereas farm prices were 39 percent lower. Net income may be lost, just as surely by sacrificing volume to price as by sacrificing price to volume—by producing too little as by producing too much. Industry makes this mistake more generally than does agriculture. But in principle the case is identical for both farmers and manufacturers. Eventually the reduction program defeats itself. Besides impoverishing the community, it injures the producers, because the resulting rise of prices fails to compensate for the loss of trade. Because urban industry is under severer restrictions than agriculture, we may consistently urge upon industry a more liberal production policy. For the long pull the good working balance between country and town demands increased production in both fields and factories.

Two Kinds of Surpluses

It is worth noting, incidentally, that the limitation of production, necessary as it may sometimes be, works against a satisfactory rural-urban balance. The object of reducing production is to get rid of surpluses and to bring supply into balance with demand. In one sense, the method works. It promotes the consumption of accumulated stocks and causes prices to rise. But in another sense, the method fails; for in the process of eliminating a surplus of goods, it creates a surplus of labor and also of capital. To limit production, competitively or cooperatively, is to limit employment. This obvious fact invites criticisms of both farm and factory controls. From the standpoint of the community as a whole, the second kind of surplus is no better than the first. All we have is a choice of evils. We do not advance toward a good working balance if in removing commodity surpluses we create surpluses of labor and capital. Both labor and capital run to waste if left in idleness, and the waste is irreparable. It is necessary to think of labor particularly in this connection; for workers must be maintained, even if their labor force cannot be used. The good working balance must include not merely a certain ratio between farm prices and nonfarm prices, and not merely a certain proportion between agricultural and industrial production, but also a shift of labor costs from tax bills to wage bills.

In a balanced economy, therefore, the removal of surpluses must include the removal from the labor market of surplus labor and of surplus capital from the money market. Obviously, this can be done only through increased production. Agriculture has an equal

interest with other industries in the matter. Its interest in parity prices coincides with labor's interest in increased employment. Overemphasis on prices, to the neglect of production, leads to scarcity. Real recovery will end this negative phase and begin a period in which both production and consumption will increase. This holds for both agriculture and industry. The ideal is production based on human needs rather than on purchasing power arbitrarily limited. To reach or even to approach this ideal requires a break, not necessarily with the control but with the restriction of production. Though more production ordinarily means lower prices, it need not mean smaller profits. Larger output at lower unit prices, with industry leading the way, is essential to safe progress toward parity prices and a fair share of the national income for agriculture. A good rural-urban balance will come about, not through extreme efforts to support prices at the expense of sales but through expansion at differing rates in fields and in factories.

The Normal Trend for Industry

It should be noted that in a balanced abundance the trend of industrial production is normally upward at a higher rate than the trend of agricultural production. This was the case throughout the nineteenth century and during the first three decades of the twentieth century. There were interruptions of the trend—particularly after the War of 1812 and the Civil War. Broadly, however, the growth of prosperity, especially in recoveries from depressions, involves an increase in industrial production relative to agricultural production and a decline in industrial prices relative to agricultural prices. This in inevitable. Wherever total production increases and living standards rise, people naturally spend more for other goods and services than for food and clothing. Their action necessitates a greater increase in industrial than in agricultural production, accompanied by a decline in industrial prices relative to farm prices. Farm production may continue to increase, though at a slower rate. Then the country moves toward a balanced abundance. Agriculture gets a fair share of the national income, not through rivalry with industry in reducing production but through fair exchange values brought about by differing rates of increase in production.

AFTERMATH OF THE DROUGHT

Weather conditions affecting agriculture in 1935 were in striking contrast with those of the preceding year. The general drought of 1934, which had prevailed over a great part of the country, came to an end. In the areas which had suffered worst, sufficient rain fell to check wind erosion, allay dust storms, and promote crop growth. The central valleys had too much rain, at any rate during the spring and early summer; and less than the usual percentage of the country suffered from deficient moisture. Of course somewhere or other in the cropped areas there is drought every year. This year, as if by way of compensation for her niggardliness in 1934, nature inflicted subnormal moisture conditions mostly on States which, nevertheless, still had sufficient moisture for crops.

The drought of 1934 began to break in the fall months, when timely rains relieved the acute situation in most regions and prepared

the soil for winter cereals. Especially favored were the eastern and northern Great Plains, which had suffered tremendously during the crop-growing season. Only in the southwestern part of the Wheat Belt did the drought persist. Additional relief came to most areas in the spring of 1935, with the continued exception of the southwestern Great Plains. Early spring rains in the northern Great Plains, where dust storms had been severe in 1934, prevented widespread harmful soil drifting, and created favorable crop prospects. Finally, in May, heavy rains fell also in southwestern Kansas, southeastern Colorado, northwestern New Mexico, western Oklahoma, and the Panhandle of Texas, and ended the droughty, dusty conditions there.

However, the droughty conditions in a considerable southwestern area, including western Kansas, western Oklahoma, the Panhandle of Texas, and eastern Colorado, were only temporarily relieved by the heavy May rainfall. For following this, June and July again had marked deficient precipitation, and drought conditions became reestablished. In fact, at the close of July, scanty rainfall and high temperatures had produced drought conditions throughout the Plains and Rocky Mountain States. Some sections of the southwestern Plains received less than one-fourth of the normal rainfall in July, and high temperatures were persistent.

In the central valleys, where drought in 1934 approached the disaster point, rainfall in the spring and summer of 1935 was excessive and caused floods and serious crop damage. Frequent heavy rains delayed spring plantings and retarded crop growth. Most spring-planted crops in the interior valleys entered the summer much retarded. Considerable acreages intended for corn could not be planted to that crop, especially in the lower Ohio Valley, in Missouri, and in southern Iowa. Missouri farmers were able to plant only about two-thirds of their intended corn acreage. Many unplanted fields in the wet areas were later seeded to forage crops. Most States further west had ample irrigation water, mountain snowfall the previous winter having been heavier, and the irrigation water supply much greater than in 1934. In the area from Montana westward, however, the precipitation was insufficient.

Up to July 1, most States had received more than their normal rainfall, particularly in the interior sections of the country, where the excess for the half year ranged from 20 to 50 percent above normal. All the States except Florida, Georgia, the Carolinas, New Jersey, and the New England group received more rain in the first half of 1935 than in the first half of 1934. In the Great Plains region the increase ranged from 140 percent of the 1934 total in Texas to 230 percent in Nebraska. States west of the Plains had substantial excesses. California, for example, had twice as much rain as in the first half of 1934, and Arizona nearly two and a half times as much.

The Continuing Effects

Though the great drought ended in 1935, its effects did not. These were chiefly of two kinds: (1) Effects on farm prices and current farm incomes, and (2) effects on farm methods and types of farming. The drought disguised the true relationship between the real capacity of our farms for production and the demand for farm products, and gave a new impulse to unbalanced production. The

significance of this may not be wholly apparent for several years, but it begins to appear in mistaken views among farmers and others as to the justification of production planning. In the fact that the drought reduced production below the point desired, many people see evidence that farm production cannot be controlled. The drought complicated the adjustment problem and raised doubts regarding the possibility of solving it; and both results will be reflected eventually in farm prices and farm incomes. Sound farm adjustment and stable farm prosperity would probably be nearer had the drought not occurred; for nature's methods of eliminating surpluses usually do not work out to human advantage.

Influence on Types of Farming

Complicated and important likewise are the direct efforts on types of farming in the drought areas and the indirect effects in other regions. In normally droughty territory the drought caused a serious loss of topsoil through wind erosion, emphasized the necessity for returning certain tracts to grass, indicated the advantages of more diversification, and showed the unwisdom of prevailing tillage methods. Also, it completed the ruin of many farmers who had been unable even before the drought to make ends meet. These effects in combination may ultimately cause farmers in the normally droughty territory to change their methods greatly.

In territory not usually droughty the worst effects of the drought will be temporary. Disturbed crop rotations and damaged pastures and legumes will be restored. Meantime farmers will resort to emergency hay crops such as soybeans and Sudan grass. Probably a permanent result will be a higher percentage of grasses and legumes and a lower percentage of grain crops in the cropping systems. There may be important temporary shifts in livestock production. In the western Corn Belt, for example, farmers are turning generally to increased cattle raising. On the whole, the tendency in this region will be to return to normal both in crop production and livestock production.

Regions in which the drought did little crop damage, such as the eastern Cotton Belt and the northeastern dairy region, will, nevertheless, feel the economic repercussions of the drought's effects elsewhere, but these indirect effects cannot be discussed as yet except in a speculative way. It is obvious, of course, that important crop shifts throughout a large region must significantly influence farming practices in other regions. The Great Plains could not turn much land from cereals to grass without affecting the crop enterprises of the dairy States and the South. Ultimately, the result might be beneficial all around; but we cannot tell in advance, or know exactly what the result would be. All we can say with confidence is that some of the consequences of the great drought will be permanent and will affect agriculture not merely in the drought territory but throughout the country.

No General Retreat Likely

It is improbable that there will be any general retreat of farming from even the worst affected areas. The Great Plains and adjacent regions suffered from drought in the years immediately preceding

1934 and bore also the handicap of low prices for their products. Many farmers in these areas had come almost to the end of their resources and had seen their debts mount and their lands and their equipment depreciate. But the soil of the Great Plains and of neighboring areas is well adapted on the whole to wheat production and poorly adapted to other types of farming. Notwithstanding the drought, the Great Plains States in 1934 raised 216,000,000 bushels of wheat, in comparison with 280,000,000 bushels produced in the States east of the western boundary of Minnesota, Iowa, and Missouri, and west of the Great Plains. Wheat production in the Great Plains will certainly not be abandoned, though it may be continued under cropping systems considerably modified and necessitating a higher percentage of feed crops and more livestock. It should be dropped, nevertheless, in certain localities where the conditions of soil and climate are demonstrably adverse. Research should differentiate the areas adapted to wheat production from those in which such farming seems hopeless, at any rate under the market conditions likely to prevail in the next few years.

This research must consider not merely the physical but the economic factors, as the physical and the economic phenomena interact. Their reciprocal influence affects productivity as well as production. Certain price conditions may encourage soil mining, and leave agriculture unable to withstand price recessions. Relatively high prices for wheat during and after the World War brought under the plow much land in the Great Plains that might better have been left in grass and exposed the soil to wind erosion. When prices and yields declined together in the drought years, thousands of farmers were unable to carry on. The problem now is to determine what types of farming should be substituted under the present economic conditions for the types that have failed. It is necessary, in other words, to recalculate the economic and physical balance and to reorganize farm production on a basis that can be maintained with the yields and the prices that may reasonably be expected. Yields that returned a profit before 1929 may be insufficient now.

The Situation in a Hard Winter Wheat Area

Farm-management specialists looked into this matter in a typical section of the hard winter wheat area, and their findings illustrate the problem admirably. They ascertained that, with production costs at the rate that prevailed in 1931, with the farm practices common to the area, and with wheat worth 70 cents a bushel at the farm, the average farm operator would need to raise at least 9 bushels an acre, one year with another, to keep out of the red. Under the cost and price conditions assumed, they could pay a land charge of 6 percent on $20 an acre, replace their worn-out equipment, and have $600 left annually as labor income. By no means all the farmers in the area could expect to raise the necessary 9 bushels an acre from year to year. Some of them, moreover, had costs above the 1931 average.

In another area nearby the wheat yields averaged only 7.4 bushels per seeded acre in 6 years out of 10. This production was materially below the level necessary to pay the farm expenses and support the farm family.

Unit costs have declined somewhat since 1931, but not sufficiently to make farming in these areas profitable at materially less than 9 bushels per acre. Land that ordinarily produces less should clearly not be in wheat. Only the best soil should remain in wheat production, and the rest should be devoted to feed crops and livestock.

This is the outstanding lesson of the drought for the normally droughty areas. It does not dictate the total abandonment of wheat as a cash crop or condemn the farmers there to perpetual insolvency. It does emphasize the wisdom of specializing less exclusively, of keeping more land in pasture and forage, and of maintaining reserves both of feed and of capital for the inevitable season or seasons of drought. Also it emphasizes the importance of better farm practices. Surveys in the subhumid Wheat Belt showed that some farmers use tillage methods that prevent wind erosion, conserve soil moisture, and produce yields above the average for the region. In regions where the uncertainty of the rainfall is a permanent hazard, careful tillage and provision for making the fat years feed the lean are indispensable precautions. Not to employ them and to rely instead on the hope of making good seasons wipe out the losses of poor seasons, is perilous when prices are good, and absolutely ruinous when prices are low.

Farm-Rehabilitation Problem

That the drought left a serious farm-rehabilitation problem in the worst drought areas goes without saying. It burdened many farmers with debt which they cannot hope to carry even under improved economic conditions, and created a difficult problem of refinancing. The Farm Credit Administration has refinanced a considerable number of farmers, but its facilities are inadequate for the extreme cases. Some creditors decline to reduce their claims in the hope that the Government will come to the rescue. It might be advantageous in many cases to let foreclosure take place, and to reestablish the displaced farmers on other farms less heavily capitalized. Part of the difficulty dates back to the overvaluation of land during and immediately after the World War; but the drought brought the trouble to a head, and indicated the necessity for dealing with capital charges as well as with the other aspects of the rehabilitation problem. The scars of the drought years in the subhumid territory will heal only very slowly, and not without attention to some very fundamental matters, foremost among which are the complete retirement of some tracts from crop growing, the modification of cropping systems in other tracts, and the revision of capital charges in line with actual earning power. Nothing causes more farm distress in the long run than false views as to what the land can permanently produce.

Grazing in much of the Great Plains area presents a problem of rehabilitation second only to that of grain farming. The National Forest Grazing Administration and the Administration of the Public Domain under the Taylor Grazing Act have to deal with two portions of our western grazing resources, but the public forests and the public domain constitute only a minor fraction of the total grazing area of the Western States. Grazing land in private ownership presents quite as difficult a problem. Overgrazing is a problem on

all our grazing lands; and, unless we take precautions, it will appear immediately on areas withdrawn from grain farming. It is imperative to reorganize range livestock production along more rational lines, with checks against overgrazing and with provision for carrying feed reserves against periods of drought. Withdrawing land from one improper use, merely to thrust it into another, is very inefficient, and improper grazing may destroy soil wealth as surely as improper cultivation.

Emphasis on Beef Production

The reduction caused by the drought in the number of livestock on farms and ranches, and the resulting rise in livestock prices, has caused many farmers in the western Corn Belt to emphasize beef production rather than dairying. This development tends to allay the fears of farmers in the specialized dairy regions that the Corn Belt may become more competitive with them. Indeed, the production of beef in the Corn Belt may go too far and may cause eventually a sharp upward movement in the beef-cattle cycle, in a reaction from the abnormally rapid decline of 1934. Farmers still respond immediately to the stimulus of rising prices, without due consideration of price prospects. The restocking of western ranches began in 1935, when heavy rains improved range conditions, and the movement will temporarily support the prices of cattle to Corn Belt farmers. The demand from ranchers for breeding stock will be substantial; moreover, shipments of feeder stock and of animals for slaughter from the range will not be in normal volume for several years. But with full restocking of the ranges, the increase of cattle production in the Corn Belt will approach the danger point. It may demonstrate for this branch of agriculture what similar tendencies may demonstrate for other branches, that the sudden removal of surpluses through drought does not remove the need for production planning.

LAND UTILIZATION

During the last half century four stages may be distinguished in the evolution of public policy toward agriculture in the United States. The first was characterized mainly by an interest in the technique of production. In that stage the Federal Government and State agencies confined their attention pretty largely to the study of ways to decrease the cost and increase the volume of the farm output. That this was not enough came to be generally recognized about 30 years ago. Then came the second stage in which public agencies added to their production studies an increasing interest in the farm as a business enterprise. It came to be recognized that markets and prices have as much to do with the individual farmer's lot as his skill in raising crops. Accordingly public agencies investigated market conditions, practices, and prices, improved their crop-reporting services, and developed facilities for the standardization of farm commodities. In the third stage the concept of public responsibility for agricultural welfare widened again. It came to include a sense of the farmer's dependence on credit conditions, land values, land tenure, methods and conditions of land settlement, and the nonfarm uses of land. The fourth stage, which may

be said to have originated with the passage of the Agricultural Adjustment Act in 1933, brought the essential features of the preceding stages into a higher synthesis, involving the whole adjustment of agriculture to its economic environment. This is the stage of comprehensive agricultural planning.

Concern with land, and with land use and land tenure, was the new aspect of public policy in the third stage of its development. Not until the policy had entered the fourth stage, however, did concern with land pass much beyond research, extension, and other educational activities. There was considerable progress in forestry and in the conservation of wildlife resources; but land settlement remained chaotic; public agencies did not try to coordinate the farm uses with the nonfarm uses of land and did not check wrong land uses. It was impossible to leave matters in that stage after the passage of the Agricultural Adjustment Act. Federal guidance in production control under that law created new Federal problems. New uses had to be discovered for land withdrawn from production for export, submarginal farming had to be discouraged, and crop adjustment had to be coordinated with land utilization in general. Crop adjustment involved land adjustment as an inevitable consequence. It would have been highly illogical to regulate the use of land in farms, and do nothing about the land not in farms. Land planning became an integral part of agricultural planning and, for the first time in our history, inspired vigorous action.

Research in Land Use

Economists in this Department had studied land questions for many years before the necessity became compelling to put their conclusions to the test of practice. They investigated the tenure question, the taxation and capitalization of farm lands, the allocation of all our land resources among the various uses, the effect of uncontrolled farm expansion and land settlement, the relationship between so-called "submarginal production" and farm welfare, the bearing of individualistic land uses on public interests, the requirements of forest preservation, flood control, the prevention of erosion, and the role of public responsibility in the conservation of soil wealth. It had been recognized for nearly a quarter of a century that the Nation should assume responsibility for the conservation of forest resources, and subsequently it came to be recognized that the same attitude should hold toward the conservation of wildlife. In these two respects study produced action. Succeeding national administrations reserved and acquired areas for national parks and forests and provided in a small way for refuges for migratory birds. On this basis of research and experience the Department is now erecting a broad and substantial land program.

It is true that the social control of forest and wildlife resources is as yet only partial. The national forests represent only a fraction of our total forest area. Four-fifths of the land capable of producing commercial timber is in private ownership, and this privately owned forest land is often poorly managed. The public has an interest in all forest lands, whether publicly or privately owned. On the management of these lands depends the permanence and stability of community life, and in no small measure the economic and social welfare

of whole regions. We have made only a beginning in the protection of areas suited to wildlife. Yet in dealing with both forest and wildlife resources we are on the right path, as the results so far realized abundantly prove; and the public interest in methods of land utilization warrants action in other directions. Accordingly, Federal money is now available not only for the acquisition of forest and wildlife areas, but for cooperation with farmers and with State agencies to check erosion, for the better regulation of grazing lands, for the improvement of national parks, for the development of recreation areas, for guidance in land settlement, for the retirement of areas submarginal for farming, and for the relocation of farm families to save community expenses and promote better land use.

A Joint Responsibility

The development of a national land policy is of course not exclusively the task of this Department or of any other single agency of the Federal Government. It is the joint responsibility of numerous public bodies both State and Federal. As a step toward coordinating different lines of attack upon the problem, the National Resources Board appointed a land planning committee, which surveyed the situation and issued a comprehensive report in January 1935. Many branches of the Federal Government cooperated in furnishing material and in drawing up recommendations. Among the cooperating units were the Bureau of Agricultural Economics, the Bureau of Agricultural Engineering, the Bureau of Biological Survey, the Bureau of Chemistry and Soils, the Forest Service, the Weather Bureau, the Agricultural Adjustment Administration, the National Park Service, the Office of Indian Affairs, the Geological Survey, the Reclamation Service, and the Soil Conservation Service. Representatives of State agencies conferred with the committee. In land planning it is essential to coordinate Federal with State programs because the States exercise a wide land jurisdiction and can do much through zoning and other methods to promote better land utilization. Moreover, much of the necessary initiative in a democracy should come from the governmental units nearest the land problem.

Public agencies engage in land planning, not for the sake of the land, but for the sake of those who use it. This principle, moreover, should not be interpreted too narrowly; for everyone lives on the land, directly or indirectly. We cannot distinguish sharply between the urban and the rural population, because the two groups interpenetrate and continually exchange personnel. There is a constant ebb and flow of population between town and country in which the controlling factor is the balance of advantage between urban and rural occupations. Needless to say, land-use conditions affect this balance tremendously. In the pioneer epoch, when land was free or cheap, everyone had an obvious interest in the fact, regardless of whether or not he wished personally to take up land. In the greatly changed conditions that prevail now, the relationship between the individual and the land, though it takes a different form, is just as vital. Accordingly, the land planning committee of the National Resources Board dealt in its report with land planning in its immediate, as well as in its more remote bearings on human welfare. The broad conclusions it announced provide a solid basis for public policy.

Findings of the Land Planning Committee

This country, with its comparatively low ratio of population to natural resources, may through wise land planning escape the hardships that other countries have suffered, the committee declared. It need not fear a land shortage. Though the United States has no land to waste, it has enough to provide for our maximum probable population and to maintain forests, wildlife areas, and recreation areas. Manifestly, however, the attainment of this end depends upon a nice adjustment between the use and the conservation of resources. Natural wealth should be available for the satisfaction of human wants, but not for getting rich at the expense of the community. Efficient land utilization, the report indicated, must rest on a new conception of our national interest, which will recognize the land resources of the Nation as the basis of its present and future prosperity and which will regard the private landowner as a trustee for society.

Specifically the report estimated that in 1960 our need for crop land will be about 30,000,000 acres greater than it is at present. It showed that we may satisfy this requirement and yet retain about 615,000,000 acres in forests and make substantial additions to national, State, and local parks and to bird and game refuges. The report also recommended that about 25,000,000 acres should be added to Indian reservations, in compensation to the Indians for land losses suffered by them under the former allotment system. It recommended a 15-year program for the Federal purchase of about 75,000,000 acres of submarginal land, including more than 20,000,000 now cultivated.

As a corollary to the last recommendation, it urged an active program with Federal and State agencies cooperating to control land settlement. It would be obviously illogical for public agencies to acquire submarginal land without discouraging the farming of similar lands not now cultivated. Yet the report did not shut the door tightly against land settlement. On the contrary, it recognized that the prevailing economic conditions may compel this country to provide for a larger proportion of its people on the land, and to abate the prevailing excessively commercial trend in agriculture in favor of a less commercial, more domestic system. It affirmed not less vigorously, however, that no substantial movement of unemployed people from urban areas into commercial agriculture should be publicly encouraged.

Action Already in Progress

These findings go to the roots of the problem. Some of them are already the basis of definite action, notably the Federal acquisition of lands unsuitable for farming, and the coordination of forest projects with wildlife conservation and the provision of recreation areas. The Federal Government has made a substantial beginning in the acquisition of lands unsuitable for farming and has broadened the program to include the purchase of other lands not used in ways consistent with the general welfare. It was necessary to broaden the program in this manner because the acquisition of farm units alone in many areas would create holdings not well adapted to public administration. By rounding out the purchase of submarginal

farms with the purchase of cutover lands suitable for reforestation and of lands suitable for recreation areas or wildlife refuges, the program becomes an important auxiliary in park, wildlife, recreation, and forest planning.

The land-acquisition program was first established as the land program in the Federal Emergency Relief Administration, and financed by funds allocated to it by a resolution of the Special Board of Public Works in August 1934. The program was to include four types of projects: (1) Agricultural demonstration projects, wherein the land acquired for retirement from farming would be converted to uses such as forestry, upland-game conservation, grazing, or combination of these uses with recreation; (2) Indian lands demonstration projects, wherein lands would be acquired for use by certain Indians to improve their economic welfare and lessen relief costs among them; (3) migratory-waterfowl projects, in which land would be acquired for winter refuges and resting places along the migratory-waterfowl flyways for the purpose of conserving migratory waterfowl; and (4) recreational demonstration projects, to retire poor lands from cultivation and convert them to recreational use wherever that seemed advisable.

These four types of projects were carried on by the land planning committee not directly but through cooperating technical agencies. The agricultural demonstration projects were the immediate responsibility of the Land Policy Section of the Agricultural Adjustment Administration; the Indian land demonstration projects were under the jurisdiction of the Office of Indian Affairs of the Department of the Interior; the migratory-waterfowl projects were carried forward by the Bureau of Biological Survey of the Department of Agriculture; the recreational demonstration projects were the responsibility of the National Park Service of the Department of the Interior.

The program was transferred to the Resettlement Administration on June 1, 1935. At that time the program consisted of 250 projects providing for the purchase of 20,551,928 acres at a total cost for land of $103,788,079. On these lands 54,563 families resided, including approximately 29,000 requiring financial assistance to obtain satisfactory relocations elsewhere. Optioning of land was in progress within 217 of the 250 projects; and 8,973,913 acres were under option, providing for a total cost for land of $38,976,741. Options covering 4,860,818 acres had been submitted to the Washington offices of the technical agencies. Options covering 3,318,532 acres had been authorized for acceptance and had been recommended to the legal division of the land planning committee for such acceptance. These options do not represent commitments of the Government until official acceptance letters have been sent to a vendor. At the time of the transfer of this program to the Resettlement Administration, official acceptances had been mailed out covering 3,044,047 acres providing for a total cost of $13,265,804.

Wide Ramifications of the Problem

In acquiring submarginal lands, the Government touches human problems that ramify throughout our whole economy. Some areas should be retired completely from agriculture. In others it suffices

to regroup farm families, and to aid them in farm management and community organization. Still other areas do not furnish an adequate family living under the prevailing methods of cultivation, but might do so were these methods changed. In some irrigation districts, for example, the number of families or the area in cultivation is too great for the water supply. Again, in parts of the Great Plains, some shift from cereals to grass is necessary to prevent wind erosion, and farm units must be larger to include pasture and livestock. Some areas which may be submarginal now might not be submarginal were they less thickly settled. On the other hand, certain areas need to be more closely settled, so that the cost per family for community services such as schools and roads may be reduced. Related to this problem in the relocation of farm families is the problem created by the drift of the urban unemployed to the open country, and the equally serious problem of what to do with rural youth that normally would go to the cities. That these are all aspects of a single problem goes without saying. That problem is nothing less than the total adjustment of our population to the available resources and economic opportunities.

In the first aspect of this great problem, the withdrawal from agriculture of land that should not be farmed, it is seldom necessary to contemplate the complete depopulation of submarginal areas. In the Lake States much land unsuited to farming is not far away from thousands of acres of comparatively good land lying unused. The transfer of population need not be total. Even the poorer areas include many fairly good farms; and the relocation of the families worst situated, on better lands nearby, raises the level of the whole community. Farm families may sometimes be relocated on lands which the present occupants are leaving, perhaps to retire, or to enter other occupations, or to send children to college. Sometimes it is possible in a district where the customary sources of cash income are declining, and where failure to discover a remedy would lead in the end to farm abandonment, to develop greater local self-sufficiency, through the communal interchange of goods and services. It is then not necessary to treat the area as submarginal.

The Trend Toward Self-Sufficiency

Adjustment of land policy to these varying requirements raises an extremely fundamental question. How far, in the present circumstances, should we encourage less commercial, more self-sufficient types of farming?

The force of events produces a trend in that direction. Much of our agriculture has always been relatively noncommercial; that is, highly dependent on production for consumption in the farm home. In 1929 nearly half our farmers produced less than 10 percent of the farm commodities sold; now, as a result of the depression, the proportion of noncommercial farmers is even greater. It increases from the necessity to support on the farms the natural increase of the rural population, as well as a return flow of urban unemployed. It the last few years the rural proportion of the population has increased; and the increase, since it forces more people to depend on farming alone, involves some drift toward a less commercialized agriculture, in which farm production increases more than the sale of farm products.

It is one thing, however, to recognize the trend and another to accept it as desirable. As a matter of fact, the development is really an evidence that the depression continues, and a spontaneous reversal of the trend would be a sign of recovery. But this does not exclude the possibility that, for the time being, some increase in farm self-sufficiency may be the lesser of two evils, the other, of course, being rural unemployment.

For many decades technical progress in certain types of agriculture steadily reduced the quantity of labor necessary to produce a given quantity of foods and fibers and tended to develop a highly mechanized, capitalist type of farming chiefly characterized by production for the market. Such highly commercialized agriculture ceases, however, to be efficient when the labor it saves can be put to no other use. There is no point in saving labor merely to swell bread lines.

The advantage of labor-saving methods tends to vary inversely with the value of labor. It disappears when, from an economic standpoint, the labor it saves is not worth saving. In such circumstances the struggle for increasing mechanical efficiency is a dissipation rather than a conservation of energy. We have to determine which course involves the greater waste of human power: (1) Increased specialization in agriculture, with its tendency to drive men off the land; or (2) decreased specialization and decreased mechanization, with the resulting decrease in the production return per unit of labor used.

In certain areas which are relatively self-sufficient already, social planning should develop self-sufficiency still further. The alternative is farm abandonment. Complete self-sufficiency is, of course, impossible; that would mean a closed family economy and a closed family culture; in short, a reversion to an extremely primitive condition. But the areas in question are not, and never have been completely self-enclosed. They have always done some business with the outer world, and their special difficulty now is that their sources of cash income are dwindling.

The land has washed and does not produce for the market at a cost sufficiently low. Rural industries which formerly gave them both a market and some part-time work have moved away. Nearby timber resources have largely disappeared. What the farmers produce for sale must be shipped too far. Instead of moving out, however, they might explore the possibilities of increased production for their own consumption and with proper guidance might develop resources now neglected. Scientific planning could lead to improved housing and sanitation, more diversified production, better preparation of food, and the local interchange of services without the use of money. More efficient types of cooperation in social life could be developed, as well as more efficient modes of direct consumption.

Landward Movements of Urban People

Quite different is the problem that arises when the unemployed move onto the land, though this problem, too, involves the relationship between commercialism and self-sufficiency in agriculture. The task of this group is to discover sources of cash income rather than to figure out means of lessening their dependence thereon. No farm

group can dispense with cash income altogether. It is naturally more difficult to develop absolutely new sources than to endure a partial drying-up of old sources.

Refugees from the cities cannot depend for the solution of this difficulty on communal interchange, for that takes time to develop and in any case will not furnish a complete substitute for cash. Indeed, the supreme objection to lodging masses of the unemployed on the land is not their inexperience in agriculture but the impossibility of maintaining them there without supplementary employment. Not enough nonfarm work can be had. The result tends to be either withdrawal from the enterprise or an unprofitable effort to raise crops for the commercial market. Essentially, the amount of outside work that can be made available to part-time farmers depends on the total quantity of nonagricultural work that the country wants done. It does not suffice merely to take work from city people and give it to rural people.

There is limited room for urban people on the land. Though the mass settlement of the unemployed on farms cannot be justified, certain groups may advantageously combine farm with nonfarm work. Suburban living, with land enough to grow food, may unite the best elements of both urban and rural life and may cushion unemployment. Moreover, good roads and the automobile are gradually lessening the concentration of employment in large cities and creating opportunities for work in the less remote rural areas. True, the decentralization of industry is not in itself a source of new employment. There may be no more employment afterward than there was before. But spreading work geographically may spread it in the economic sense, too; it may enable more people to accept half-time jobs. As a means of allaying the pangs of unemployment, that is not to be despised.

The Main Obstacle

The cash-income problem is a fundamental obstacle. So-called "subsistence farming" will not furnish subsistence; and as the number of families seeking part-time work increases, the difficulty of providing them with the necessary supplementary income increases too. This may be inferred from the results of a survey in Maryland, in 1933, covering 82 part-time farm families in suburban areas and 59 similar families in rural areas. Besides what they raised, the families in the suburban areas purchased food averaging $369 worth per family; and in addition, they had to pay $100 more for taxes and house upkeep. Naturally, the suburban families had a much larger income from nonfarm employment than did the rural families. On the other hand, the rural families had lower farm-operating costs; and though their sales were lower also, they averaged only $20 short of covering the cash expenditures. Most of the rural families produced vegetables and fruits but not in a sufficient variety. As the distance from urban centers increases, it becomes harder to get supplementary income, and in a heavy migration the problem would become unsolvable.

Tenancy Increasing Fast

Underlying most aspects of land planning is the problem of tenure. Without a stable and continuous association with the land, farm

operators have little incentive to take care of the soil or to develop cooperative forms of economic and social life. Prosperity, individual or social, consists of two elements: (1) Income, and (2) security in the possession thereof. Farming, which usually earns less money than other occupations, normally is securer. It partially offsets the smallness of the money returns with some assurance that the farmer will not lose his job. In recent years, however, farming as a way of life has lost stability. The proof is seen in the appalling recent increase in farm tenancy; and, as is well-known, farm tenancy is a highly precarious mode of living in the United States. Both the 1925 and the 1930 censuses of agriculture show that less than half of our tenant farmers had occupied their places 2 or more full years. Long-time land planning must include vigorous attention to this problem.

In the half century from 1880 to 1930, the number of farm tenants in the United States more than doubled. The number of tenants among each 1,000 farms increased 136 percent. Forty-two percent of all the farmers in 1930 rented all the land they operated, and an additional 11 percent rented part of their lands. Since then tenancy has increased further, as a result of bankruptcies and foreclosures. In many counties of the South, at the time of the 1930 census, more than half of the farmers were tenants. In some counties, in which the farmers were nearly all whites, three-fifths of the farmers did not own an acre. Less than one-fifth of the farmers in these counties were classed as owners, and even these men were usually carrying mortgages.

It is manifest that such conditions, with their threat to sound farm practice and their discouraging influence on human beings, make efficient land planning extremely difficult. Tenant farmers in the United States seldom improve the farms they operate, because they usually do not get compensation for their improvements if they have to move. Other countries, notably Great Britain, require landowners to compensate tenants for the improvements they make. Like action here would make tenant occupancy more stable and would protect and improve the farm plant. More security of tenure for tenant farmers would increase their interest in community developments and in other things that depend for their value on a stable association with the land.

The Beginnings of a Policy

As yet we have made only a beginning in dealing with the tenancy problem. Congress recently amended the Farm Credit Act so as to authorize the Land Bank Commission to make loans for the purchase of land by tenant farmers. A pending measure would create a Farmers' Home Corporation, Government owned and controlled, with a capital stock of $50,000,000 and authority to issue bonds in an amount not exceeding $1,000,000,000. This measure, which was introduced by Senator John H. Bankhead and Representative Marvin Jones of Texas, would make it possible to promote the ownership of family-sized, owner-operated farms in quite a different manner from the mere extension of more liberal credit. The bill would set up a national field organization with local subsidiary officers, through which tenant farmers could be aided and directed in be-

coming owners. The corporation would purchase land and resell it to tenants on a long-time repayment plan under conditions giving the purchasers all the security, opportunity, and incentive of owners. As further study of the land question throws more light upon tenure conditions it should be possible to develop methods which will reconcile the interests of landowners, of tenants, and of the community, and harmonize them with a more scientific utilization of our total land resources.

WILDLIFE

Land planning must consider wildlife, which is a valuable resource in itself and has claims that we cannot ignore with impunity. Wildlife is a crop. Its production depends on the reservation and development of suitable lands. Failure to provide for wildlife is distinctly bad national economy. Not every piece of land capable of raising agricultural crops should be put to that use as the crops may be worth less than what the land would produce in its natural state. Moreover, the so-called "reclamation" of certain areas by drainage may cause floods, heavy soil erosion, and other damage. Flood control and the prevention of soil erosion may, indeed, depend greatly on the conditions that also favor wildlife and wilderness areas. Land better adapted to wildlife than to farming may actually, if indirectly, support more people if correctly than if incorrectly used. The return to wildlife of land now in agriculture may seem to involve a sacrifice of human interests, but it need not. On the contrary, the economic advantage of protecting fur bearers, game animals, and birds, and simultaneously of conserving water, soil, and forest resources may be very great.

Wildlife in this country is only a vestige of what it once was; yet even so the return from it to agriculture and industry is probably half a billion dollars annually. We can increase that return substantially by means which also protect other important natural resources. The restoration of wildlife to barren areas requires the planting of vegetation and the protection of water levels. These measures check soil erosion, help to prevent floods, and even mitigate the effects of drought on farming areas nearby. Maintaining vegetation is the best means of conserving soil moisture and preventing soil blowing. The Bureau of Biological Survey conducts a waterfowl-restoration program that illustrates these principles. Besides aiding wildlife to increase, the program helps to correct evils traceable in part to our national mistakes in land utilization. For example, it restores marsh and other submarginal lands to their primitive uses, with the result that poverty competition in agriculture diminishes, the wildlife output increases, trappers and hunters do better, and various industries profit from the sale of trapping and hunting equipment. The land acquires economic value for recreation purposes, and it becomes a national asset for soil conservation and flood control.

Effects of Unwise Drainage

Heretofore we have dealt with marshland without fully considering the consequences. The drainage ditch has taken away from our waterfowl something like 77,000,000 acres in the continental area of the United States. Some of the land thus reclaimed has become

valuable for agriculture, but a great part of it has not. Large acreages have been made useless for wildlife without becoming useful for anything else. Formerly, the marshy valley of the Blitzen River and Lake Malheur in Oregon was one of the most prolific waterfowl areas in the country. Drainage ruined it for waterfowl, and finally drought ruined it for agriculture. The Bureau of Biological Survey is now reflooding and rebuilding the area for wildlife purposes. Within a few years the section will be restored to nature's original purposes and will be producing million-dollar crops of waterfowl and other valuable forms of wildlife. Lake Malheur was a Federal migratory-bird refuge of 80,000 acres before the Bureau began the reflooding project. The addition of nearly 64,720 acres last year, under conditions giving the Government full control of the water, makes it possible to reflood the entire area. This is just one example of many wildlife restoration projects now under way. Funds for the waterfowl-restoration program became available in the latter part of June 1934, and since that time more than 800,000 acres, most of it classified as submarginal, have been acquired for use as waterfowl sanctuaries.

In recognizing that wildlife is entitled to its share of land and water and should have adequate areas for its exclusive use, the Government does not subordinate to wildlife other interests that may be more important. This country has land enough for every need of agriculture, industry, and recreation. We can have wildlife, forest, and wilderness areas, and natural water reservoirs, without encroaching at all on the agricultural and industrial uses of land. It is simply necessary to allocate land among the right uses and to correct the chaos that has resulted from the lack of such a policy in the past. Wildlife is the most valuable product obtainable from many submarginal areas. It is worth far more than it costs. The conservation of fur and game animals, of waterfowl and other birds, and of fish, while important in itself, is also part of farming and of forestry and potentially profitable. Fur and game species may be treated as a crop, and revenue may be derived from the leasing of shooting rights.

Wildlife in the Land-Use Program

The program for retiring submarginal lands from agriculture gives the Nation an opportunity to return a considerable acreage to its original and best use. In some cases the return of submarginal lands to wildlife will require direction and supervision. In others, noninterference with the habitat and habits of wild animals and birds will suffice. Nature left to her own devices may create more wealth for man than man himself could create in the same areas in agriculture or other occupations. As the land-utilization program develops it should be possible to place under public ownership a number of large tracts for administration as natural wilderness areas. The object is the preservation of the wilderness itself and of the forms of organic life that naturally occupy it. The Migratory Bird Treaty Act of 1918 and the Migratory Bird Conservation Act of 1929 provided for the Federal administration of the migratory-bird resource, and during the year 1932 wildlife refuges were started at strategic points on the waterfowl-breeding grounds or flyways in 21

States, and additional areas are now being examined and acquired. Congress has appropriated $6,000,000 for this program, which when completed will add another 1,000,000 acres to the area devoted primarily to wildlife.

Big game and all other forms of nonmigratory wildlife are not under Federal jurisdiction, except on lands owned and administered by the Federal Government. All species in this category have diminished greatly and some have even been exterminated where they were formerly abundant. It is the task of the Federal Government to prevent the same disaster on the lands within its control. This is a simple undertaking, in comparison with the difficult and expensive task of restoring marsh and water areas to preserve migratory waterfowl and other forms of aquatic wildlife.

Biological and Economic Problems Linked

It is extremely important, in framing laws for the preservation and conservation of fur animals, to consider the biological and the economic problems together. Heretofore the length of trapping seasons has been established exclusively in the belief that fur is at its best during extremely cold weather. Other factors should be taken into consideration also. The production of fine-quality fur, under conditions permitting the retention of sufficient breeding stock, requires a correlation between prime fur periods and molt cycles on the one hand, and breeding and gestation periods on the other. Trapping without regard to these requirements tends to exterminate the fur resource.

Success in the protection of fur animals is not yet assured; yet we have reason to feel encouraged. The beaver, once our most important fur animal, cannot be restored to all its former haunts; but it could be reintroduced in some localities. Besides providing a supply of fur, the beaver would do good as a water conservator along mountain streams, and thus help to prevent floods and erosion, and in some places it would also improve the value of streams and lakes for fishing. This is just one example of the many opportunities that can be developed, through Federal and State cooperation and with the aid of individuals and groups interested in wildlife conservation, to restore a heritage that has been well-nigh lost. Wildlife conservation in the United States is emerging from its period of trial and error and is developing sound practices based on research and experimentation.

FORESTRY AND ECONOMIC RECOVERY

Forest lands offer a striking example of the American record of land misuse. These lands constitute almost one-third of the area of continental United States. Three-quarters of them—and four-fifths of all the most valuable or commercial forest lands—have long been in private ownership. On these, fires have burned more than 41 million acres annually; ax and fire together have devastated or crippled close to 74 million acres.

Forest empires have been destroyed and sawmills shut down and workers scattered—those left in these empty shells of communities have no market for their labor or the produce of their agriculture.

Taxes have become delinquent, and homes and buildings have been abandoned or have been sold for miserable prices. Forest exploitation has left behind it a trail of ghost towns and rural slums, and its effects have soaked deep into the national fabric. With hillsides naked of forests, rains have run off quickly, and floods have been aggravated; the topsoil is eroded from fertile acres; streams, dams, and harbors have been loaded with silt; property has been damaged and human lives lost.

Now, after 150 years of mismanagement, we are attempting to put our forest lands in order. In this tremendous task, people are re-employed; hope replaces despair. Through emergency forest work, forest lands become a vital factor in the fight for recovery.

Our national emergency forest-work program, however, forms part of a comprehensive plan conceived long before the depression; forest projects have been so planned and executed that the work is essentially an investment. It is noncompetitive with industry. Rebuilding men, it contributes to human welfare. Rebuilding forests, it helps lay foundations for permanent economic prosperity.

The Department's Forest Service has taken the lead in the expansion of emergency forest work through the Civilian Conservation Corps, public works, civil works, transient relief, and drought relief. A high percentage of direct labor was employed. The national forests alone, in 37 States, Alaska, and Puerto Rico, furnished more than 26,000,000 man-days of planned work during the year ended June 30, 1934. Preliminary figures for the fiscal year ended June 30, 1935, indicate that the Forest Service planned and supervised a total of work on and outside the national forests in excess of 43,000,000 man-days. Operating in part through State conservation agencies, the Forest Service planned and supervised more than 70 percent of the work projects of the Civilian Conservation Corps. This calendar year, the aim is to nearly double the Civilian Conservation Corps and its work program.

Relation of Forestry to Agriculture

There are some 495,000,000 acres of commercial forest lands in the United States, directly affecting the economic life of communities. In some regions, successful agriculture can continue only if forest management creates and maintains nearby markets for farm crops. In others, farm population depends on forest work to produce cash incomes, with farm work producing the bulk of the food supply. In many sections, permanent agricultural civilization depends on irrigation—which, in turn, is dependent upon the maintenance of plant cover on the sources of water supply. This, in turn, depends upon forest and range conservation. In still other regions there is the huge task ahead of substituting forest production for agricultural production on worn-out or abandoned farm lands.

Economic and social welfare in many sections is largely dependent upon forest-land forage. Within the continental United States some 334,000,000 acres—more than 50 percent of all commercial and noncommercial forest lands—are grazed by domestic livestock. The western national-forest ranges play an important part in the agricultural economy of large sections. These ranges were used last year by

more than 1,400,000 cattle and 6,000,000 sheep; the forage produced on these ranges is essential to the enterprises of some 26,000 stockmen.

For 30 years the national-forest ranges have been under administration as a continuing public resource; on them, drift fences, corrals, and bridges have been built, water supplies developed, roads, trails, and stock driveways constructed, and poisonous plants eradicated. Always the effort has been to issue permits only for the number of stock that the amount and condition of the available forage justified. As a consequence, western national-forest ranges came through 1934 in relatively good condition.

Although the drought relief committee found it necessary to purchase but few of the livestock which grazed on these ranges, the drought had its effect nevertheless. Under the 10-year grazing permits, initiated in 1925, numbers of stock could not, in some instances, be reduced sufficiently or quickly enough successfully to meet range conditions induced by the wide-spread subnormal precipitation that culminated in 1934. As a result, some national-forest ranges, built up prior to 1925 through use under the more flexible annual permits, are not now what they should be. They need rebuilding. Therefore, to obtain a partial rest for the ranges, long-term permits, which expired with the 1934 season, have not been renewed. Grazing permits are again issued on an annual basis. National-forest ranges are being built up so as to contribute to the maximum number of those home units which are dependent for success upon use of national-forest forage.

Correlation of Land Purchases

Recently, a land policy committee was set up in the Department to meet the need for coordination and correlation of all land-purchase work and to provide for unity of action in other than forest-land purchase programs for such purposes as wildlife refuges, control of soil erosion, curtailment of submarginal farming—programs necessary and advisable in the public interest. The committee acts as a clearing house for all land purchases of all departmental bureaus.

Forest Research

Forest research is today a vital activity, the essential background of all forest work. The major part of the effort in this field is now concentrated in the Forest Service. Provision is made for basic silvicultural, range, watershed, economics, and products investigations. The current Congress provided for the establishment of a Rocky Mountain Experiment Station, which will constitute the twelfth of a series of regional stations, which, with the Forest Products Laboratory, are intended to cover the forest problems of the entire United States.

The diversity of forest research is illustrated by such current activities as the studies in the construction of inexpensive, modern homes, studies of the condition and weight of cattle as affected by use of range forage, and economic investigations which bring out the wide-spread need for a sounder credit basis for forest production.

Despite the universal use of wood, our per capita consumption of wood fell sharply, even in predepression years; and so, in the face of increased population, did the total consumption. A national

timber famine has not yet actually materialized, although since normal forest drain exceeds normal forest growth by a ratio of nearly 2 to 1 (5 to 1 for saw timber), our forest supplies are waning. The need for research and for the development of new uses and markets for wood is evident. But there is also a real need to conserve our forest resources, to add to them by growing forests on all lands most valuable for forest purposes.

SOIL CONSERVATION

Critical situations in the use of land in any large country may result from causes either economic or physical, or from both together. Land-use problems may arise from overproduction and low prices, or from soil deterioration. Though both types of land crisis diminish the incomes of farmers and reduce the Nation's standard of living, the remedies are not necessarily identical. Crop adjustments may temporarily solve the economic problem without solving the physical problem. Such adjustments, by matching supply to demand, may raise farm earnings; but whether they will also conserve fertility, prevent erosion, and promote good land use depends on the provision they make for intelligent, comprehensive. and sustained action to that end.

There is no necessary contradiction between controlling production on the one hand and building or rebuilding productivity on the other. Nevertheless, it is possible to do the first and neglect the second, and the mistake may have grave consequences. In long-time agricultural planning the policies which increase current farm incomes should be linked with efforts to protect the physical body of the soil. Coordinated to realize these two ends simultaneously, agricultural planning promotes the interests of consumers equally with those of producers, because, while regulating the volume, it reduces the costs of production. Crop adjustments undertaken without care for the soil lack this necessary feature and may fail to command general approval.

For this reason the Agricultural Adjustment Administration is cooperating with the Soil Conservation Service and with extension workers and farmers in efforts to tie in crop adjustment with soil conservation. It will help us to grasp the significance of this joint effort if we notice some of the physical problems involved.

Some causes of soil depletion may be remedied easily, whereas others may not. Soils protected against erosion may decline steadily in plant food as a result of improper cropping; but in that case the physical body of the soil remains, and frequently fertilizers will restore the plant nutrients. But soil stripped bodily from fields by rain or wind is lost—usually forever. Soil depletion of the first type, through the loss of plant nutrients that can be restored, may make farming temporarily unprofitable; but the second type of soil depletion—erosion—may make farming permanently impossible. Forces that merely reduce the profitableness of agriculture for the time being do not compare in ultimate importance with those that destroy the basic soil resources.

Physical Aspects of the Present Crisis

That the present crisis in American agriculture has physical as well as economic aspects is now a familiar fact. Recent dust storms, after

last year's drought, apprised the whole country of it, and drew attention forcibly to the problem of soil erosion. Formerly we were only dimly aware of the truth that the soil is not an inexhaustible, abundant, and immutable factor in our farm economy and that land exploitation finally must give place to land conservation. Not until the frontier had dissolved into the Pacific did we realize that the opportunity to abandon worn-out land for new was gone. Up to that time we had been imbued with a pioneer psychology that was indifferent to the soil lessons of history and to contemporary practice in other countries.

A physical crisis in agriculture, coming on top of an economic crisis, shook us out of this lethargy, warned us dramatically that our ratio of population to productive land resources is going up, that practically all the better lands have been occupied for agriculture, that much formerly fertile land has been ruined or greatly impoverished, and that considerably more land will go the same way unless we take steps to save it. It may be useful, before describing the soil-conservation work now in progress, to indicate why it is necessary. This takes our story back to the Indians, who did little to change the virgin character of the land surface and its vegetation. In their day rivers draining the densely forested areas generally ran clear except in high flood. Vegetation ranging from grasses to dense forests covered the larger area of the country, protected the land surface from rainwash and favored the absorption of rain and melting snow. There was little surface washing. Such erosion as did occur was of a geological or normal character and did not exceed the rate of soil formation. Then the white man came with ax and plow and livestock. Advancing rapidly, farmers, lumbermen, and stockmen pushed the frontier farther and farther westward, cleared the land of forests, turned the prairie sod, and overstocked the range. They bared millions of acres to the wash and sweep of rain and wind, and soils which had been thoroughly protected for thousands of years began to erode.

Types of Erosion

Wind and water are the agents of accelerated erosion. Erosion by water is the more serious evil and is of two major types—sheet erosion and gully erosion. Sheet erosion takes a thin layer of soil, more or less evenly, from entire sloping fields. Its severity usually varies with the degree of slope, the character of the soil, and the type of vegetative cover on the land. It is probably the most widespread form of erosion and at the same time the least noticeable. Farmers usually fail to recognize it until they find their top soil gone. They may even see that their soil is changing in color without realizing that erosion is the cause.

Gully erosion is usually the aftermath of advanced sheet erosion, although it may develop independently as the result of the concentration of run-off water. This concentrated flow of water has sufficient force, especially where sheet erosion has exposed the highly erodible subsoil, to cut rapidly into land. In many sections of the country the resulting gullies have reached an enormous size and have destroyed thousands of acres of land for practical agricultural use.

Wind erosion has always been active on loose sandy soils. Under certain conditions it becomes destructive on fertile loamy soils. Such conditions have been accumulating in this country over a long period. Cultivation and overgrazing, which tend to deplete the humus supply and to pulverize the soil, have exposed vast areas to the sweep of winds across the Great Plains. Dried by several years of drought, small, light particles of soil blow high into the air and drift great distances. Coarser, less productive particles roll along the surface until stopped by some obstruction, and sometimes bury crops, fences, and even buildings. Wind erosion occurs principally within the semiarid sections of the Great Plains where the annual rainfall is less than 25 inches. It is growing serious, however, in other parts of the West, notably in the Big Bend section of Washington and certain areas of the overgrazed western ranges.

Erosion damages not merely the land from which it strips the surface but also bottom lands on which infertile material is deposited. It silts up reservoirs and stream channels, increases flood hazards, and diminishes the water-storage capacity of watersheds. Reservoir silting as a result of erosion is an important problem in many localities. Stream channels shallowed by deposits of erosional debris are far more susceptible to flood. Accelerated run-off from unprotected uplands adds volume to the storm waters flowing into the main drainage stream in the watershed.

It is estimated that erosion costs the United States approximately $400,000,000 annually in soil depreciation and reduced yields. This figure does not include the damage to navigation, water power, irrigation, and water-supply developments.

An Erosion Survey

In 1934 the Soil Erosion Service, then in the Department of the Interior and since transferred to the Department of Agriculture under the title of Soil Conservation Service, made a reconnaissance survey of 1,907,000,000 acres representing the total area of the country exclusive of urban and water territory.

On 578,167,670 acres in nearly all parts of the country, the survey indicated little or no erosion of any kind. In an area comprising 857,386,922 acres, sheet erosion was generally prevalent in degrees ranging from slight damage to complete destruction.

Wind erosion had affected a total area of 322,961,231 acres, principally in the middle western States. This aggregate included some 88,000,000 acres seriously damaged or practically ruined for productive purposes.

Gully erosion had caused severe damage generally on approximately 337,000,000 acres, with about 4,000,000 acres so badly cut up as to be unfit for practical cultivation.

Through its Soil Conservation Service, and in close cooperation with the States, the United States Department of Agriculture is directing a national movement to protect and conserve our land from accelerated erosion. It is developing practical and effective methods of control through research and experiment, and is helping to demonstrate these methods under varying conditions. The research phase of the Federal program is carried on at erosion experiment stations in Iowa, Kansas, Missouri, New York, North Carolina,

Oklahoma, Pennsylvania, Texas, Washington, and Wisconsin. Demonstrations in practical control are being carried out in cooperation with farmers on selected watershed areas in every major agricultural region of the country where erosion is a serious problem.

Within these demonstration-project areas, through cooperation with landowners and operators, the Soil Conservation Service carries out a complete and carefully balanced program of soil protection, in which the various methods of erosion control are applied singly or in combination according to the peculiar needs and adaptabilities of each type of land requiring treatment. The development of such a coordinated program involves consideration of natural land factors such as climate, land slope, soil formation, and vegetation.

Practical Control Measures

Practical measures in the control program fall generally into three main categories: (1) Adaptations of thick-growing vegetation to practical farm operations; (2) use of engineering structures, such as terraces and dams; and (3) the retirement of excessively eroded land from cultivation. It is impossible, in dealing with this many-sided problem, to rely in large measure on any single, unsupported method. All available methods, such as correct cropping and rotations, engineering aids, pasture and forest development, and land retirement, must be welded into a composite program of land treatment. Adjusted to the requirements of different kinds of land as determined by soil, slope, rainfall, and the type of farming, the work on the demonstrational areas fits in well with regional and national land-use objectives.

Broadly, the procedure in demonstration areas involves surveys, cooperative agreements, and field work. Each project area is mapped first from the air and then in detail to show the field lay-out of every individual farm, the location of fences, wooded areas, streams, and other physical features. With these maps as a basis, field workers of the service and the farmer together draw up practical plans for the stabilization of all eroded areas. These plans, which may call for a considerable reorganization of farming practices, become the basis for cooperative 5-year contracts between the farmers and the Government.

COTTON

Three crops of cotton have now been produced in the United States under Agricultural Adjustment Administration adjustment programs, and the administration has offered new contracts to cotton growers covering a 4-year period beginning with the crop of 1936. These programs have fulfilled their purpose, which was to prevent the continued overproduction of cotton. The program in 1933 removed from production about 10,500,000 acres. In 1934 and 1935 the programs withheld, respectively, about 14,600,000 acres and 14,000,000 acres from production. Each program reduced the world carry-over of American cotton. At the end of the 1934–35 season the carry-over totaled about 9,000,000 bales, as compared with about 13,000,000 bales on August 1, 1932. Yet the carry-over was still far above predepression levels.

Cotton prices have risen greatly in the period covered by the adjustment programs. In the 1934–35 season the average farm price

was 12.4 cents a pound, as compared with 6.5 cents during the 1932–33 season. The 1934–35 average price was 79 percent of parity. At their lowest point in 1932, cotton prices were only 37 percent of parity. Farm income from cotton and cottonseed, including rental and benefit payments, was $839,000,000 in 1934–35 and $862,000,000 in 1933–34. In 1932–33, the season preceding Agricultural Adjustment Administration crop adjustment, the return was only $464,000,000. Present indications are that the figures for 1935–36 will show a still further increase, constituting the largest gross income from cotton and cottonseed since 1930.

It may be useful briefly to describe the adjustment machinery. Under the Agricultural Adjustment Act, the administration enters into contracts with growers providing for rental and benefit payments in return for specific adjustments in their acreage. Supplementing the contracts is the Bankhead Cotton Act of 1934, which imposes a heavy tax on the ginning of cotton produced above the allotments. In addition, the Commodity Credit Corporation makes loans available to cooperating producers. In the 1933–34 season the loan value was 10 cents a pound. This was increased to 12 cents in the 1934–35 season. In 1935 the Agricultural Adjustment Administration announced a modification of the cotton-loan plan. The loan value was reduced to 10 cents and a new feature added to the loan agreement whereby producers who agreed to cooperate in crop adjustments during the 1936–37 season will receive adjustment payments equal to the amount by which 12 cents exceeds the average price of Middling 7/8-inch cotton in 10 designated spot markets on the date on which the producer sells his cotton. This adjustment is limited to 2 cents a pound and does not apply to cotton produced in excess of allotments under the Bankhead Act.

The Cotton Loans

Large numbers of growers obtained loans in 1933–34 and 1934–35. In the 1933-34 season the market price of cotton advanced well above the 10-cent loan value, and the loans were largely liquidated. Toward the end of the 1934–35 season, however, the market price of cotton tended to fall below the loan value, which as already noted had been raised to 12 cents a pound. The result was that by the end of the year the Government was holding about 4,500,000 bales as loan collateral. It had extended the maturity date of the loans to January 1, 1936. Stocks of Government-financed cotton constituted practically the entire surplus stock. Stock in trade channels and in mills had been reduced to normal or subnormal levels. It was extremely desirable to move the accumulated stocks into export and into domestic consumption. Reduction of the loan rate to 10 cents a pound promoted that end, with cooperating growers protected by the adjustment payments previously mentioned.

Rental and benefit payments to cooperating cotton growers totaled $112,600,000 in 1933–34 and $115,800,000 in 1934–35. In 1935–36 the rental and benefit payments will amount to probably $125,000,000. Taxes collected on the first domestic processing of cotton largely defrayed the costs of the adjustment programs without adding materially to the retail prices of cotton goods. On an average, for the three seasons during which the crop adjustments have been

in effect, the farm prices of cotton plus the rental and benefit payments have approximately equaled parity or fair-exchange value as defined in the Agricultural Adjustment Act so far as the domestically consumed portion of the crop is concerned.

Enactment of the Bankhead Act in 1934 followed a questionnaire survey which indicated that most growers favored the principle involved. In 1935 the administration took a referendum to determine whether the growers wished to continue with that method. About 90 percent of those voting favored doing so. Accordingly, operation of the Bankhead Act was continued for the 1935–36 season. There is no doubt that the provision for taxing cotton produced above allotments increased the effectiveness of the cotton programs in 1934 and 1935. Furthermore, the system provided cotton growers in drought-stricken areas with a certain amount of crop insurance. They had the privilege of selling their unused exemption certificates to other growers at the rate of 4 cents a pound of cotton, or of retaining the certificates for use the following year. Most growers whose production exceeded their allotments purchased exemption certificates, in preference to paying the ginning tax, the rate of which was 0.67 cent a pound, with the result that approximately $13,800,000 was distributed to growers in Texas and Oklahoma through a national pool organized to provide facilities for the transfer of tax-exemption certificates. Ginning taxes collected during the first year of the Bankhead Act amounted only to $1,123,524.

Need for Continuing Adjustment

There is evident need to continue the cotton-adjustment program. The carry-over of American cotton at the end of the current season will be far above normal, and a return to unrestricted production would mean a return to low prices. With growers planning their production independently instead of in concert, our cotton production could easily increase to 15,000,000 or 16,000,000 bales annually. In only three seasons has the world used more than 15,000,000 bales of American cotton, and these were seasons of exceptional business activity at home and abroad, during which, moreover, the United States was financing our exports through loans. It is highly desirable to increase our sales of American cotton abroad, but we may do that for some time without increasing our production. Our accumulated stocks, with adjusted production, give us the means of supplying all probable demands.

Certain long-time factors in the cotton situation, with which the Agricultural Adjustment Administration programs have nothing to do, should be borne in mind. Though the total consumption of cotton has increased in foreign countries during the last 25 years, the exports and the foreign consumption of American cotton have been barely maintained. Indeed this country exported more cotton in the 5-year period ended with the fiscal year 1914 than in any subsequent 5-year period. For 40 years the production of cotton has increased somewhat more rapidly in foreign countries than in the United States. Nationalistic policies in many countries have accentuated the trend. An important factor is the increasing industrialization of the Orient and the development there of cotton spinning and weaving. Oriental countries that formerly imported

cotton goods from the United States and Europe are now large exporters of such goods; and the raw material they use is mostly non-American cotton. The large use of foreign cottons in the Orient results partly from the nearness of the mills to the producing areas and partly from the fact that foreign cotton growers have the advantage of cheaper labor. These differentials tend to offset the relatively high waste and stoppage loss in the spinning of foreign cottons. Moreover, many foreign cotton-producing countries have devalued their money more than the United States has devalued the dollar, and cotton prices have responded to a greater extent than most other agricultural prices. This has brought additional land into cotton production.

Foreign Trade Should Not Be Sacrificed

It does not follow that we have lost our foreign markets for cotton irrecoverably or that the United States should adjust itself to a domestic-production basis. But the time has not come for abandoning the cotton-adjustment programs. As we know from the continued presence of surplus stocks in this country, the United States has not reduced its power to supply the foreign demand. The 12-cent loan probably held back exports for a time, but the modified loan program will correct that tendency. American cotton is the standard in world trade and offers the largest even-running quantities. The potential demand for American cotton is large in Europe, in Canada, and in the Orient, and a well-considered adjustment program will not sacrifice it. It is important not to restrict production too drastically and not to forget that price is only one of the factors in farm income. Cotton farmers should not produce at a loss, in order to maintain the Nation's exports; but neither should they underestimate their ability to compete with foreign growers.

WHEAT

Commencing during the crop year 1933, approximately 800,000 farm operators and landlords have participated in an effort to apply the principle of cooperative action to the adjustment of wheat production. The fact that 1,328 wheat-production-control associations have been organized and that farmers have been successful in performing the local administrative functions is now well known throughout the agricultural sections of the country.

Since 1933 the wheat surplus has been reduced, prices in the United States have maintained levels substantially above world prices, and the cash income received by wheat producers, including adjustment payments for the 1934 crop, was practically double the cash income for the crop of 1932. Farmers have demonstrated their ability to cooperate in an effort of this kind and have given their endorsement to a continuation of the program.

Although the principal proportion of the reduction in the surplus was caused by the drought of 1933 and 1934, the wheat program provided means for making a much larger adjustment than was necessary under existing conditions. Thus, the wheat-adjustment program has demonstrated its practical application during three most unusual seasons. The plan lends itself to upward as well as down-

ward adjustments and permits changes in the adjustment policy to meet changing physical and economic conditions.

The wheat-allotment contract, approved in the summer of 1933, provided for a maximum downward adjustment of 20 percent in wheat seedings. Because of the drought of 1933 and 1934 and the rust epidemic of July 1935, adjustments of this magnitude were not warranted, and consequently the required adjustments for the crops of 1934, 1935, and 1936 have been 15, 10, and 5 percent, respectively. Furthermore, the requirements as to use of contracted or adjusted acreage were modified so as to offset in part the shortage of livestock feed occasioned by the drought.

On July 31, 1935, it was announced that a 15-percent reduction would be required in seedlings in the 1935–36 crop year. At that time the available data based on the July crop report indicated a wheat crop for 1935 of 731,000,000 bushels, which would have provided a substantial surplus from the 1935–36 crop year, and would in all probability have resulted in an increase in the carry-over on July 1, 1936. as compared with that on July 1, 1935. When the August crop report was published, however, it was discovered that the spring wheat crop had been damaged as a result of one of the most severe rust epidemics in history. This materially changed the prospective wheat situation. In view of this changed situation, planting requirements for 1936 were modified so that a downward adjustment of only 5 percent from the base was required in the 1935–36 crop year.

Consumers' Interests Considered

By means of these changes in adjustment requirements, consumers have been protected by ample supplies of wheat. The carry-over of wheat on July 1, 1935, was 152,000,000 bushels, which is about 27,000,000 bushels larger than the average for the period 1920–28. The operation of the wheat-adjustment program contemplates an acreage in the United States which, over a period of years, will produce a substantial surplus above domestic requirements.

The interest of consumers is protected under the wheat-adjustment program not only in the assurance of adequate supplies, but also in assurance against excessively high prices. Under this plan the processing tax is adjusted upward or downward in accordance with the difference between the average farm price and the wheat-parity price. The parity price is based upon pre-war purchasing power of wheat in terms of the cost of commodities farmers buy, interest on farm indebtedness, and taxes on farm real estate. Thus, the cost of wheat to the miller is stabilized at or near the parity price. With parity at $1.10 to $1.15 per bushel, the processor pays no more for his raw material when the price of wheat is $1 than he does when the price is 50 cents. This stabilizes the cost of wheat and should have an equally stabilizing effect upon the cost of bread.

Experience has also shown that the principles embodied in the wheat-adjustment program will permit the United States to maintain a substantial volume of export trade. Short crops in 1933, 1934, and 1935 have made substantial reductions in the amount of United States wheat available for export. In all of these crop years, however, some export trade has been secured. Total exports of wheat and flour amounted to 21,532,000 bushels during the 1934–35

crop year, as compared with 37,001,000 bushels during 1933–34 and 41,211,000 bushels during 1932–33. Under the wheat-adjustment program, when normal yields are obtained and the United States has a surplus, our wheat will be sold in such a manner as to meet competition in the markets of the world. Anticipated plantings for the 1936 crop will, with normal yields, result in at least 75,000,000 or 100,000,000 bushels for export, and a similar amount would have been available in 1935 had it not been for the dust storms and the rust epidemic.

World Wheat Situation

The world wheat situation is characterized by continued tariff and import restrictions which maintain acreage and production in importing countries at relatively high levels. These policies tend to cause the world trade in wheat to prevail at lower levels than the relatively large volume of international trade which characterized the 1920's. Under present conditions a total volume of world shipments greatly in excess of 600,000,000 bushels does not appear probable during the next few years. The present level of production in exporting countries will produce a surplus somewhat in excess of the anticipated import requirements. The United States stands ready to cooperate with other nations in bringing about an adjustment of world production to demand. It is believed that an effective international wheat agreement will be hastened if this country continues to produce a sufficient amount of wheat so as to remain an active participant in world trade. In furtherance of this policy, plans for 1936 have been modified so as to permit the production of an exportable surplus of wheat in addition to increasing domestic reserves.

The Wheat Price Outlook

Until world-wide adjustments in wheat production have been made, the price of wheat to farmers in the United States will in all probability prevail at levels below the parity price. Under these conditions the income to wheat producers in the absence of adjustment payments would be less than their equitable share of the national income. Under such circumstances wheat producers will benefit from adherence to the principles of the wheat-adjustment program, which provides them a measure of income insurance and maintains their purchasing power at levels substantially higher than would otherwise prevail. The attitude of wheat producers is evidenced in their overwhelming endorsement of the principles of the wheat-adjustment program in the wheat referendum which was held on May 25, 1935.

In looking to the future of agricultural adjustment as it applies to wheat in the United States, attention needs to be given to the problems of different wheat-producing regions. There are four major wheat-producing regions in the United States; namely, the soft red winter wheat region, the hard red winter wheat region, the hard red spring and durum wheat region, and the white wheat region of the Intermountain and Pacific Coast States. The production of hard red spring and soft red winter wheats has approached a domestic basis for a number of years, whereas exportable surpluses have arisen primarily in the case of white and hard red winter wheats. The regions producing these types of wheat, however, appear to have a compara-

tive advantage for wheat which has caused farmers in these regions to maintain their acreage in the face of declining prices. The various classes of wheat are interchangeable in a large degree, and in view of this interchangeability and comparative advantage in surplus-producing regions, no feasible method has as yet been devised for providing for different adjustments in different regions. This problem is receiving the attention of the Department of Agriculture and the land-grant colleges and requires the careful consideration and study of wheat producers generally.

THE LIVESTOCK SITUATION

Livestock production is recovering slowly from the 1934 drought, but the country's meat supply will be subnormal for another year or two. It takes time to replace breeding stock, the foundation of the annual meat supply; and it takes still more time for the progeny to be raised and fattened. The number of livestock on farms on January 1, 1935, was the smallest since early in the present century. The shortage resulted directly from the drought, which tremendously reduced pasturage and grain and hay crops. Livestock numbers would have been even smaller this year, had the Agricultural Adjustment Administration not acted last year to prevent excessive liquidation, and to make the liquidation that was inevitable as orderly as possible. Hog farrowings in the fall of 1934 were only about half those of the fall of 1933, and the spring farrowings in 1935 were less than two-thirds as large as those in the spring of 1933. The 1934 and 1935 corn-hog adjustment program had no appreciable effect on these farrowings, the smallness of which was the result primarily of the drought.

Government action undertaken in 1934 and early in 1935 for the relief of the cattle industry conserved foundation stock. The Government purchased more than 8,000,000 cattle and turned over to the Federal Surplus Relief Corporation all animals fit for human consumption. This action mitigated the effects of the drought in two ways: (1) It increased the supply of meat available for 1934, because otherwise many of the animals would never have reached slaughter houses; and (2) the purchase program reduced death losses on farms and ranches and enabled growers to save breeding stock. Cattle slaughter under Federal inspection in 1934 was the largest since 1926. Had the Government not furnished a market outlet, cattle prices would have declined to a point that would scarcely have paid marketing costs. Large numbers of cattle in the drought areas could not have been sold, and death losses would have been vastly greater. Besides conserving meat supplies, current and prospective, the cattle-purchase program increased the income of the cattle producers. Gross returns to cattlemen in 1934, including $112,000,000 paid by the Government for drought cattle, were probably 75 percent greater than they would have been otherwise.

Meat production depends in the long run on the feed available; but after heavy reduction in livestock numbers, the limiting factor temporarily is the time required for breeding and rearing. It is necessary to keep the feed supply in balance with the rate of increase in livestock numbers. The 1934 corn crop was the smallest since 1894, and was less than half the pre-war average. This year's corn pro-

duction on the other hand is large in relation to the reduced feeding demand. According to the September estimate, it was about 2,184,000,000 bushels. Though nearly 400,000,000 bushels below the average for the years 1928–32, the crop will provide the largest supply per hog on farms January 1 since the World War. Moreover, the supply of other feed grains and of forage will be ample likewise. All told, the grain supply per grain-consuming animal will be as large as in any year since the war, and the supply of hay available per hay-consuming animal will be the largest of any year, with one exception, during the same period. Any greater increase in feed production would have simply depressed feed prices without immediately increasing the supply of meat.

Adjustments Lessened Drought Effects

Crop-adjustment contracts entered into by farmers lessened the bad effects of the drought last year and facilitated a return to more normal production this year. Thus in 1934, when the drought became serious, the Administration authorized plantings of late-sown feed and forage crops on land under contract and permitted contract signers to plant corn for forage on contracted acreage. These steps increased the production of feed materially. The supply of late-sown crops, such as soybeans, was larger than in the previous year. The spring pig crop in 1934 was smaller than it would have been had farmers not entered into adjustment contracts; and this fact, too, helped to promote an orderly liquidation of hog numbers when the feed shortage became acute. The emergency reduction of hog supplies in the fall of 1933, with the 1933–34 corn-loan program, had resulted in the carrying over of some 50,000,000 bushels of corn and corresponding amounts of other feeds from the 1933 crop. Thus the feed supply per animal unit was larger than it would have been had the control programs not been undertaken.

In 1935 the Administration offered to farmers a corn-hog program which restricted the planting of corn but not the planting of other feed crops. Also the Administration made a supply of adapted seed available to producers in drought areas. As a result, the acreage of oats, barley, and grain sorghums increased 10 percent above the 1928–32 average. Yields were only slightly below normal, and the production of these grains was 5 percent above the 1928–32 average, and two and one-half times as large as in 1934. The contract called for a reduction in the corn acreage for two reasons. In the first place, the number of grain-consuming animals on the farms was the smallest in 35 years; and in the second place, the usual farm practice of planting more corn acreage in years following droughts would have resulted, with average yields, in a corn supply far in excess of feeding requirements. Adjustments made by the contract signers held corn production more nearly in line with livestock needs.

Under the 1935 corn-hog contract, the individual farmer had to retire from corn production not less than 10 percent nor more than 30 percent of his base corn acreage. The benefit payment was 35 cents a bushel for the appraised corn yield. Signers retired in the aggregate 23 percent of their base corn acreage, or nearly 12,000,000 acres. About 93,000,000 acres of corn was harvested, as compared

with the 1928–32 average of nearly 103,000,000 acres. As already mentioned, the yield was only slightly below the average, and the supply of corn per hog on farms is now the largest since the war. Without a corn-acreage limitation, the 1935 corn crop would have created a burdensome surplus. The production might have equaled 2,800,000,000 bushels, and the supply of corn per grain-consuming animal would have been much greater than in any other post-war year.

Corn Adjustment Necessary in 1936

Some adjustment in the corn acreage should be made again in 1936, if the supply of corn is to be kept in line with feeding requirements. On a harvested acreage equal to that of 1935, average yields would provide a supply of corn per grain-consuming animal equal to that of any year since the World War. Average yields on an unadjusted acreage would give a supply much in excess of feeding requirements. There is feed enough on hand and in prospect for next year, assuming average yields, for materially increased hog production. Just now there is a shortage of hogs; and a marked increase in hog production is desirable. Care should be taken, nevertheless, to prevent the upswing from going too far. Exports of American hog products annually since the World War have declined by the equivalent of 8,000,000 head. The increase in the domestic population partly offsets this decline in the foreign demand, but a supply of hogs as large as the post-war average would carry hog prices down far below parity. Recovery from the effects of the drought requires continuous crop adjustment rather than a return to unrestricted production.

DAIRY PRODUCTS

Prices of dairy products have been much higher in the last 2 years than they were in 1932 and early in 1933. In fact, the general trend has been upward since March 1933, in which month the farm-price average was only 71 percent of the pre-war level as compared with 157 percent in 1929. For the second half of 1933 the average was 91 percent of pre-war; for the second half of 1934 it was 100 percent. The average for the first 4 months of 1935 was 116 percent of the pre-war level. There was a recession during the summer; and for the months June to August, inclusive, the average was 98 percent of pre-war.

Several factors contributed to the uptrend. Demand conditions improved in 1933, marketing agreements and licenses under the Agricultural Adjustment Act exerted a steadying influence, and Government purchases of dairy products for relief distribution removed stocks from trade channels. Dairy conditions were still unfavorable at the beginning of 1934. Though milk production per cow had dropped to the lowest point in 8 years, the total milk production was not much below the peak of 102.3 billion pounds reached in 1933; and the number of milk cows in the country as of January 1, 1934, was 17.3 percent greater than it was 5 years previously. However, the drought of 1934 changed matters greatly, and dairy production dropped off.

Government purchases of drought cattle, heavy liquidation of cattle numbers in the ordinary channels of trade, and the Federal

program for the eradication of cattle diseases brought about a decrease of 4 percent in milk-cow numbers in the second half of 1934. Moreover, pasture conditions were so poor and feed supplies so short that milk production per cow declined to the lowest point touched in 11 years. This drop in production, though it carried the total for the year down only to 3.3 percent below 1933, added another strong influence to the factors already operating for price recovery. The shortage of feed supplies other than pasture held milk production relatively low in the winter of 1934 and the spring of 1935, in which period the output of butter in particular was down. Part of the major butter-producing region had been hard hit by the drought.

Pasture conditions improved in 1935, and milk production per cow increased substantially. During most of the pasture season total milk production was 4 or 5 percent greater than in 1934. It should be kept in mind that, notwithstanding the moderate decrease that took place in milk-cow numbers in 1934, the productive capacity of the dairy industry is still very large in relation to the demand. Animals eliminated from herds in 1934 were mostly low producers, and their elimination had only a minor effect on total production capacity. Fairly liberal supplies of roughage and of other feeds are in prospect now, and numbers of other farm livestock are much reduced. Therefore, the production of milk in the next year or two may exceed the large outturn of 1933. Such an increase in milk production would tend to offset the influence of the improved demand and to depress returns to producers.

Government Purchases of Dairy Products

In 1933 leaders in the dairy industry urged Government purchasing of dairy products to remove surpluses from commercial channels and undertook to support a production-adjustment program. The Government began purchasing in August 1933 and by April 1934 had bought 45,769,000 pounds of butter and 6,346,000 pounds of cheese. It purchased additional quantities later with funds provided under the Jones-Connally Cattle Act. From May 1, 1934, to April 30, 1935, the quantities purchased were as follows: Butter, 16,176,000 pounds; cheese, 11,574,000 pounds; evaporated milk, 37,596,000 pounds; and dry skim milk, 6,526,000 pounds. From May 1 to November 8, 1935, contracts were awarded for the following amounts: Butter, 7,064,000; cheese, 194,000; evaporated milk, 9,431,000; and dry skim milk, 9,322,000. Deliveries on the latter quantities have not been completed. These products were all distributed through relief channels. In accordance with the plan for an adjustment program, the Agricultural Adjustment Administration in April 1934 offered a program involving benefit payments for cooperative adjustments in dairy production, but dairymen appeared to be about equally divided for and against it. It is the policy of the administration not to proceed with any adjustment program without the support of a substantial majority of the interested producers. Accordingly, the dairy program was withdrawn, and the industry continued to rely on marketing agreements, which deal of course only with the existing supply of milk and milk products. Indications are that the need for more fundamental adjustments still exists.

Small Danger of Significant Imports

There is little prospect of developing important foreign outlets for our dairy products. In recent years the industry has been practically on a domestic basis; and dairy prices in the United States are far above dairy prices in the major butter-importing countries. It is not likely that trade negotiations can overcome an obstacle of this character. In fact, with dairy production increasing in other countries there is a possibility of imports into the United States. Thus, in the first half of 1935, domestic butter prices went for a time above foreign prices by more than the amount of our tariff, which is 14 cents a pound, and 21,487,000 pounds of butter came in over the tariff barrier. However, butter imports for the 3 months, July to September, dropped to 448,000 pounds, and we exported 244,000 pounds. At the current level of world prices, the level of prices in the United States could rise substantially above that of the summer of 1935 without attracting any significant volume of imports.

TOBACCO

For about 375,000 farmers in 28 Southern and Eastern States the principal sources of cash income is tobacco. Usually the production of tobacco in the United States is about 1,400,000,000 pounds, about 40 percent of which is exported. This total production is made up of several distinctly different kinds, each grown in a particular section of the country. Flue-cured tobacco and burley tobacco are the most important kinds; about 60 percent of the former normally is exported; nearly all of the latter is consumed domestically.

Beginning in 1930, the consumption of tobacco declined both at home and abroad. Our exports dropped, and large surpluses accumulated. Tobacco prices fell to very low levels. In 1931 the tobacco crop was about as large as that of 1929; yet it brought the growers only $130,000,000, as compared with $286,000,000 from the 1929 crop. The crop of 1932 was the smallest in several years; and though growers received a higher average price than that for the 1931 crop, the farm value of the 1932 crop was only $107,800,000, or 60 percent less than the value of the 1929 crop. This was the situation for which Congress provided remedies in the Agricultural Adjustment Act.

When this act was passed the growing season for most kinds of tobacco was so far advanced that it was not practicable to bring about adjustments in the 1933 production except in the case of the cigar-leaf types, which are planted later in the season than other types. Other procedures under the act, however, were used to improve the situation which tobacco growers faced.

When the flue-cured tobacco markets opened in 1933, prices fell so low that growers demanded the temporary closing of the markets. After growers signified a willingness to adjust the production of succeeding years, the Administration negotiated a marketing agreement with the principal buyers whereby they agreed to purchase certain quantities of the 1933 crop at or above a specified price. Similar agreements were arranged for burley, fire-cured, and dark air-cured tobacco when growers gave assurance that supplies would be adjusted in succeeding years. As a result, growers received 65 per-

cent more for the 1933 tobacco crop than they did for the 1932 crop.

In 1934 the Agricultural Adjustment Administration entered into adjustment contracts with approximately 275,000 growers in continental United States and 10,500 growers in Puerto Rico. The contracts covered about 88 percent of the land on which tobacco is usually grown. The resulting adjustment in tobacco production reduced the excess stocks on hand by about one-third. The surplus of flue-cured tobacco was eliminated; supplies of other types, however, were still excessive, particularly those of burley and cigar-leaf tobacco.

Producers' Income From Tobacco

Income to producers from tobacco in 1934 was more than double that of 1932, not including benefit payments. With benefit payments amounting to $43,136,000 included, the total income from the 1934 crop was $266,315,000, as compared with a 10-year average (1919–28) of $270,602,000. The total return gave the growers a purchasing power exceeding the 10-year average by 25 percent.

The 1934 contracts were continued in 1935, and growers who had not signed contracts received another opportunity to do so before planting their crop. Also, the Administration provided special base contracts for growers who had previously produced tobacco but who could not establish bases in the ordinary way. These special base contracts took into consideration the personal production history of the growers, as well as their land, labor supply, and other producing facilities.

The 1935 crop is estimated at 1,120,000,000 pounds, as compared with 1,046,000,000 pounds in 1934, and an average of 1,433,000,000 pounds for the 5 years 1928–32. The flue-cured crop is about 25 percent larger than it was in 1934, and above the 5-year average. Consumption of this type, however, is increasing, both in the United States and in the United Kingdom, and the crop is not out of line with requirements. The burley, fire-cured, and dark air-cured crops are about the same as in 1934, and substantially below the 5-year average. But for these types the market outlook is less encouraging. Burley tobacco, about 95 percent of which is consumed domestically, is not so well adjusted to the demand as some of the types more dependent on exports. Shifts in consumption and international trade restrictions continue to affect the markets for fire-cured and dark air-cured tobacco. Production of cigar-leaf tobacco in 1935, though somewhat larger than in 1934, was less than half the 5-year average; but the consumption of this type is very low, and the surplus is still large. The need for adjustments in tobacco production is a continuing one.

In response to the requests of growers, Congress passed the Kerr Tobacco Act, which was approved June 28, 1934. The act levied a tax of 33⅓ percent of the gross sale value of all tobacco harvested in the crop year 1934–35 except Maryland, Virginia sun-cured, and cigar-leaf tobacco, but authorized a tax rate of not less than 25 percent if the lower rate would accomplish the desired end. For the 1934 crop the minimum rate was in effect.

Producers operating under adjustment contracts received tax-payment warrants with which to pay the tax. Similar warrants in

limited amounts were issued to noncontracting growers in each county who were unable to obtain equitable allotments under contract. After the passage of the Kerr Act, growers were given another opportunity to sign contracts, and many did so.

Referendum on Kerr Act

In December 1934 and January 1935 the Administration took a referendum to see if the growers favored a tax on the sale of tobacco for the crop year beginning May 1, 1935, as provided in the Kerr Tobacco Act. The returns covered more than 90 percent of the acreage customarily devoted to tobacco. Approximately 90 percent of the growers of the flue-cured, fire-cured, dark air-cured, and cigar-filler and binder types favored the tax. Accordingly, it became effective for the 1935 crop, this time at the full rate authorized in the legislation.

All the original tobacco contracts terminated with the 1935 crop; and in July the Agricultural Adjustment Administration conducted a referendum to determine whether the growers desired another program. All landlords, tenants, and share-croppers were invited to vote. Nearly 75 percent of the growers eligible to vote did so; and more than 95 percent of those voting favored continuing the program. After the referendum, Agricultural Adjustment Administration representatives conferred with advisory committees of tobacco growers regarding the principles and details of proposed new contracts.

On July 29 a program was announced for flue-cured tobacco, the kind marketed earliest in the year. In effect the new program continues, for the 4 years 1936 to 1939, the program that was in force for the crop years 1934 and 1935, but contains new features. The principal changes are in providing for more equitable distribution of allotments among individual growers and greater simplification of the contract and administrative procedure. Similar contracts are being prepared for other types of tobacco.

In the recent amendments to the Agricultural Adjustment Act, Congress fixed the processing taxes on tobacco at the rates then in effect. Provision was made, however, for certain changes to correspond with changes in tobacco prices. Specifically, the amendments prescribe that if the average price for tobacco during the 2 months immediately preceding a marketing year and the first 10 months of that year is less than the fair exchange value by not more than 10 percent, or exceeds the fair exchange value by 10 percent or less, the rate of tax shall be adjusted at the beginning of the next marketing year to 20 percent of the fair exchange value. Should the average price exceed the fair exchange value by more than 10 but not more than 20 percent, the rate must be adjusted to 15 percent of the fair exchange value. If the average price exceeds the fair exchange value by more than 20 percent, the rate must be adjusted to 10 percent of the fair exchange value.

Changes in Processing Taxes

In accordance with these provisions, adjustments were made in the processing taxes on tobacco, effective October 1, 1935, as follows: For Burley tobacco used in the manufacture of products other than chewing, the rate was reduced from 6.1 cents per pound, farm-sales

weight, to 3.5 cents per pound; the rate for Maryland tobacco was increased from zero to 3.62 cents per pound, farm-sales weight; for fire-cured tobacco the rate was increased from 2 to 2.14 cents per pound for that used in chewing tobacco and was reduced from 2.9 to 2.14 cents per pound for that used in other products; and for flue-cured the rate was reduced from 4.2 cents per pound, generally, and from 2 cents per pound for tobacco used in the manufacture of chewing tobacco, to 1.89 cents per pound, farm-sales weight, for all uses.

After investigation and hearings it was determined that the full processing-tax rates provided for cigar-leaf tobacco generally, for cigar-leaf tobacco used in the manufacture of scrap chewing, and/or smoking tobacco, and for Burley tobacco used in the manufacture of chewing tobacco, would cause such a reduction in the quantity of these kinds of tobacco or the products thereof domestically consumed as to result in the accumulation of surplus stocks or in the depression of the farm price of these kinds of tobacco. It was found that the rates previously in effect were the highest rates that could be levied without having such results. Accordingly, these rates were made effective October 1.

The average price for the 1934 crop of dark air-cured tobacco was less than fair exchange value by more than 10 percent. The processing tax for dark air-cured, therefore, remained at the rates in effect at the time of passage of the amendments to the Agricultural Adjustment Act.

SUGAR

Substantial progress has been made in the complex program of adjustment of sugar supplies to requirements. The sugar problem differs in several respects from that of most of our other basic agricultural commodities. A sugar-beet and sugar-cane industry of considerable importance in certain areas of the country has become established mainly as the result of tariff protection. Three-fourths of the sugar we consume is produced outside of the continental United States. A large part of this production is in our own insular possessions or Territories or Cuba, with which producing area we have had special trade relations.

In the formulation of an adjustment program for the sugar industry it was necessary to protect the right of our domestic producers to an appropriate share of the United States sugar market in a manner to yield the producer the maximum benefit, impose the minimum cost on the consumer, and at the same time enable the United States to deal fairly and satisfactorily with her insular areas and foreign countries supplying the United States market.

Before the enactment of the Jones-Costigan amendment to the Agricultural Adjustment Act, the protective tariff was the traditional and sole device used to protect the interests of domestic sugar producers. The tariff, however, was not effective in maintaining returns to growers. Our insular areas operating behind the protection of a high tariff, increased their production and in their effort to displace a large portion of the duty-paying Cuban sugar in the United States market, competition was intensified.

The sugar program made possible by the Jones-Costigan amendment seeks to assure for domestic producers a fair share of the

domestic market through a quota system, and to supplement the income of producers by benefit payments for their cooperation in adjusting production. In addition, adjustments by producers in our insular areas are compensated by benefit payments.

During the year and a half that the sugar plan has been in effect surplus sugars in the continental United States and insular areas have been eliminated. Adjustments in production have been made in the domestic sugar areas as well as in the principal United States insular areas supplying sugar to this country. The principal curtailment of surplus was in the Philippine Islands, where Philippine planters were confronted with a substantial adjustment of production in view of the Philippine Independence Act. That act provides for a limitation of duty-free importations of sugar into the United States to 956,000 short tons annually. Through cooperation with the adjustment program, Philippine planters were able to receive adjustment payments to aid them in making the transition to a lower level of production required by the independence act. Continental and offshore supplies have been brought into closer balance with consumption requirements with resultant strengthening of price.

General Results of the Program

The income of producers generally has increased, and in those localities of the United States sugar-beet area where the 1934 drought drastically reduced production, benefit payments under the sugar-beet program were of unusual importance in maintaining farmers' income. These results have been achieved without materially increasing the cost to consumers. Returns to laborers in the beet fields have been increased directly through wage determinations by the Secretary of Agriculture, and in other sugar-producing areas provisions protecting laborers have been included in the production-adjustment contracts. Positive action toward the elimination of child labor in the sugar fields has been taken. Compliance with child-labor restrictions and wage and labor provisions of the farmers' contracts with the Government is a prerequisite to benefit payments.

Quotas were established as outlined in the act. Minimum annual marketing quotas of 1,550,000 short tons of sugar for the domestic beet-sugar industry and 260,000 tons of sugar for the domestic sugarcane industry were established. The quotas for the offshore areas were based upon their average shipments to the continental United States during the 3 "most representative years" of the period 1925–33, in accordance with the provisions of the act. In view of the quotas established in the act the domestic beet-sugar producers have in effect, in their production-adjustment program, agreed to produce at a stabilized level in return for the added income which the quota provisions of the act and benefit payments make possible. The basic quota of 1,550,000 tons for beet sugar is higher than the marketings of any previous year and higher than the production of any year except the record year 1933. In comparison with past production, the quota is substantially above the average for the 9 years 1925–33, although 12 percent below the high year 1933. The domestic sugarcane basic quota of 260,000 tons is higher than the production in any year of the 1925–33 period.

70,000 Producers Cooperating

Through the mechanism of production-adjustment contracts approximately 70,000 producers are cooperating in the sugar-beet program. The goal of the production is a production approximately equivalent to the national beet-sugar marketing quota. Despite the extreme drought 1934 sugar-beet income of farmers, including benefit payments, amounted to nearly $57,000,000, slightly higher than that from the record 1933 crop. Louisiana producers signed approximately 9,000 adjustment contracts, and under the program their 1934 cash income was approximately $16,000,000 as compared with $11,000,000 in 1933. The sugar producers of Florida and sugarcane sirup producers also have derived benefits from the act under separate programs developed for them.

In the insular areas similar adjustment programs have been put into effect. The 1934–35 Philippine sugar production was reduced from an estimated 1,571,000 short tons to 694,000 short tons in order to absorb in 1935 the 400,000 tons carry-over from the 1933–34 Philippine crop. Philippine production for the crop year 1935–36 will approximate 1,100,000 short tons. Benefits to about 19,000 Philippine producers for reducing production during the 1934–35 crop year and maintaining production during the 1935–36 crop year to the quantity necessary to produce its United States quota, provide for local consumption requirements, and maintain its 100,000 tons emergency reserve will be approximately $16,000,000. In Puerto Rico contracts were entered into with about 8,000 producers. In the aggregate production of sugar has been reduced by approximately 313,000 tons as compared with the record crop of 1933–34. The curtailment was brought about without destruction of cane by utilizing a considerable part of the excess cane for conversion into molasses for distillation and feedstuffs purposes, and by reducing plantings to about one-third of normal and carrying over surplus cane into the new crop year in replacement of such deficiencies in planting. It is anticipated that a total of $12,000,000 will be disbursed as benefit payments on the 1934–35 crop. In Hawaii a 3-year program is in effect seeking to stabilize production at about 975,000 tons annually. Adjustment payments are estimated at $8,750,000 annually.

Expenditures From Special Funds

In addition to benefit payments the insular areas have received benefits under the sugar-adjustment programs by various expenditures for the benefit of agriculture out of special funds created under the Agricultural Adjustment Act for that purpose.

Pursuant to section 15 (f) of the act as amended, the President has established separate funds in which are held processing taxes collected on the sugars from the various areas, which funds are to be used for the general benefit of agriculture in the respective areas. Up to date projects have been approved for Puerto Rico and Hawaii, including soil surveys, insect-pest surveys and control, tropical-plant experiments, erosion work, and similar purposes.

As a result of the quotas and the tariff reductions made on Cuban sugar in 1934 under provisions of the Tariff Act of 1930 and the Trade Agreement with Cuba of 1934, the cost and freight price for Cuban sugar sold to the United States has increased by about 70

percent and our trade with that area increased markedly after the sugar program and the reciprocal trade agreement with Cuba became effective in September 1934. During the first 11 months of this agreement trade between Cuba and the United States increased 60 percent.

The processing tax of one-half cent a pound which finances the sugar program has not increased the cost of sugar to the consumer, since the imposition of the tax was accompanied by a reduction in the tariff of an equal amount.

RICE

Rice is a basic commodity under the original form of the Agricultural Adjustment Act, but the Administration did not immediately launch a production-adjustment program financed by processing taxes for this commodity. Instead it undertook in 1933 to adjust supplies and promote higher prices through marketing agreements. This course seemed advisable, because the rice industry is relatively small and geographically compact and because in the California area the growers and millers had had previous cooperative experience. However, rice is grown also in a group of Southern States—Arkansas, Louisiana, and Texas. Conditions in the California rice area differ greatly from conditions in the southern area, and the marketing-agreement method proved better adapted to the former than to the latter area. In both areas the agreements helped to control production and raise prices to growers, but certain difficulties developed in the southern area which indicated that a production program financed through processing taxes would be more satisfactory. Accordingly, under an amendment to the Agricultural Adjustment Act, the Administration offered to growers a control program based on a processing tax and benefit payments for 1935–36.

The first marketing agreements entered into provided for minimum prices to growers and minimum conversion charges to millers for the sale of rough rice. They became effective in the autumn of 1933. The California agreement contained also an acreage-control feature, and subsequently a like feature was incorporated into the southern agreement. In California all the millers and practically all the growers agreed to the production-control plan, the mechanics of which involved the retention of part of the agreed price, for distribution later to growers, on proof that they had fulfilled their obligations. In the southern area, on the other hand, a minority of the rice millers declined to cooperate. It became necessary, therefore, to issue a license to all millers, but the license did not contain provisions for production control. The nonsignatory millers, according to the terms of the license, had to pay producers the full price for their rice at the time of purchase. There were noncooperative producers, as well as millers, in the southern area. These noncooperators were able to get more for their rice from nonsignatory mills than cooperating producers could get immediately from signatory mills. The resulting difficulty caused signatory millers to doubt the value of the program, and in September 1934 it became necessary to modify the production-control mechanism, the vital feature of which was the arrangement for differential payments as between cooperating and noncooperating growers. In March 1935

the Administration terminated the southern marketing agreement and shortly afterward announced plans for a program similar to those in effect for other basic crops.

Results of the Marketing Agreements

The marketing agreements achieved much for the growers, despite the difficulties encountered in the southern area. They kept acreage in check in the face of rising prices. The price of domestic rice advanced well above world levels and, indeed, made temporarily an excellent market for Philippine rice, which may enter the United States duty free. The acreage actually planted approximated the allotments, and the resulting production approximated the quotas originally assigned. The production of rice in 1934 was 38,296,000 bushels, or only 4,212,000 bushels above the aggregate of the quotas.

Some evidence of the effectiveness of the agreements appears in a comparison of rice prices in recent years. Extra Fancy California-Japan at San Francisco, in 1934–35 was $3.78 per hundred pounds, as compared with $2.40 in 1932–33. Extra Fancy Blue Rose at New Orleans was $3.75 per hundred pounds in 1934–35, as against $2.25 in 1932–33. The farm price of all grades and varieties of the 1934–35 crop averaged nearly twice as much as that of the 1932–33 crop. The total farm value of rice in 1934, according to the crop estimates of December 1934, was $29,662,000,000, as compared with $16,116,000 in 1932.

Special provisions for rice adjustment under a processing tax-benefit payment plan are contained in the DeRouen rice bill, which was enacted March 18, 1935, as an amendment to the Agricultural Adjustment Act. This measure authorizes a processing tax at the rate of 1 cent a pound for rough rice, effective April 1, 1935, until July 31, 1936. It exempts clean rice from the provisions for floor stocks taxes. It provides for tax-payment warrants in payment of the processing tax on rough rice of the 1933 and 1934 crops purchased under the previous marketing agreements and licenses. In addition, the bill sets up machinery to export surpluses of rice from the 1933–34 crop under conditions permitting the maintenance of domestic prices.

The program launched under this legislation eliminates most of the difficulties experienced under the marketing agreements. Under the processing-tax feature it puts all mills on the same basis with respect to the purchase of rice; and by imposing a compensating tax on rice imports, it prevents imports of Philippine rice except at levels comparable with domestic prices. Rice produced in this country can again be exported, at least in quantities sufficient to prevent the accumulation of surpluses. The program provides for an export rebate equivalent to the processing tax paid; and the exports for the 3 months following April 1, when the processing tax became effective, amounted to 76,000,000 pounds, as compared with 18.000,000 pounds in the corresponding period last year.

POULTRY AND EGGS

The poultry and egg industry is one of the most important branches of agriculture. In 1934 its products brought a gross income of $653,932,000, and this return was exceeded only by the income

from milk and cattle and calves. The 1930 census reports nearly 5,500,000 farms, or approximately 5 out of every 6 farms in the United States, as producing poultry and eggs; and 76.9 percent of these farms have flocks of less than 100 fowls. The fact that it is made up of such small units makes difficult the solution of the industry's problems by adjusted or controlled production.

Many thousands of handlers are engaged in collecting, processing, and shipping poultry products for use locally as well as to more distant markets. The interstate aspects of this trade made it possible, under the National Recovery Act, to develop codes of fair competition with certain branches of the industry, under the dual administration of the National Recovery Administration and the Agricultural Adjustment Administration. Several marketing groups, including the baby-chick-hatchery group, submitted codes for consideration. Conferences and hearings followed. On January 2, 1934, the Commercial and Breeder Hatchery Code became operative; and on April 23, 1934, a code became operative for the live-poultry industry of the metropolitan area of New York. Considerable work was done to develop regional codes with other marketing branches of the industry, but these codes were never completed.

The Commercial and Breeder Hatchery Code was Nation-wide in effect and involved between 12,000 and 14,000 producers of baby chicks and chick dealers. It was in operation during two hatchery seasons, and benefited the poultry industry generally as well as the hatchery industry. The giving of secret rebates, failure to deliver chicks as agreed, substitution of chicks without the buyer's knowledge or consent, false and misleading advertising, and various forms of misrepresentation were to a great degree eliminated.

Poultry-Improvement Plan

As originally approved the code contained a mandatory provision requiring the code authority to develop, in cooperation with this Department and other interested agencies, uniform terms, rules, and regulations for flock improvement. Such a program was submitted to and approved by this Department and is now in operation. This is known as " the national poultry-improvement plan ", the purpose of which is to create a uniform basis and terminology for flock improvement, and similarly, a uniform terminology and program for disease control as relating to chicks.

The hatchery industry has taken advantage of an offer by the Federal Trade Commission to aid in continuing the progress made through the code with respect to fair-trade practices. It has revived and put into effect trade rules which have the approval of that Commission.

In 1934 the estimated wholesale value of the products handled by the live-poultry industry of the metropolitan area of New York was $27,647,367, and such products were shipped to New York from 31 States. In the period, a little over a year, during which the live-poultry code was operative, it accomplished an estimated annual saving of over $100,000 to shippers of live poultry through reduction of coop and cartage costs. Also, it served to stabilize the live-poultry market in New York by requiring a report of expected shipments, by continuing the official inspection of live poultry, and by

correcting objectionable and unfair trade practices. The *Schechter case*, which involved violations of this code, was selected by the National Recovery Board as a test case before the United States Supreme Court to determine the validity of certain portions of the National Recovery Act. As a result of the decision in this case, all codes were declared invalid.

Since poultry and eggs were not included as basic commodities under the Agricultural Adjustment Act, the only method open to the administration at present for assisting in the problems of this industry is through the use of marketing agreements. Before entering into such agreements, it will first be necessary to study the essential economic facts. Such a study is now under way, and it will furnish a guide in formulating future policies.

RYE

The recently approved amendments to the Agricultural Adjustment Act called for a production control program for rye. Accordingly, the Administration held public hearings at Aberdeen, S. Dak., August 29, 1935, and at Washington, D. C., September 6, 1935, at which farmers and others testified regarding the present and prospective price of rye and regarding features of the proposed program. The amendments provided for a processing tax of 30 cents a bushel on rye, and this rate will be effective from September 1, 1935, until December 31, 1937, unless it is modified in harmony with a specific formula set forth in the legislation. Rye regulations issued by the Secretary established conversion factors for determining the amount of processing tax to be imposed on different rye products. Included in the regulations was a statement calling attention to the marketing years as fixed in the amendments to the Agricultural Adjustment Act, the first marketing year being from September 1, 1935, to June 30, 1936, and subsequent marketing years from July 1 to June 30.

Rye production in the United States in 1935 was estimated as of August 1, at 52,200,000 bushels, or about 20,000,000 bushels above the average annual domestic consumption. In 1934 the production was only 16,040,000 bushels; the 5-year average (1929–33) was 35,167,000 bushels. With an export surplus in prospect, an adjustment program was considered necessary to establish a balance between the production and consumption of rye and to restore the commodity to fair exchange value. As of August 15, 1935, the estimated average farm price of rye was 35.5 cents a bushel. Fair exchange value on that date was 92.9 cents a bushel. In 1934–35, when rye was on an import basis, the farm price averaged about 75 cents a bushel. The depressing influence of the season's exportable surplus is reflected in the present wide disparity between farm prices and the fair exchange value.

The rye program will run parallel with the new wheat contract. Cooperating producers will limit their rye acreage for harvest as grain in accordance with the requirements of domestic and foreign markets, but in no year may they be required to reduce their acreage harvested as grain below 75 percent of their acreage of rye harvested as grain in the base period. Allotments to individual farmers will depend on acreage and yields in the base period but in addition will be subject to modification in accordance with definite regulations.

This flexibility in the determination of individual allotments should help farmers who have recently begun to produce rye. The advance payment in 1936 will be at the rate of 20 cents a bushel on farmers' allotments, and the total 1936 payments will be at least 35 cents a bushel on the farm allotments, unless rye prices should rapidly rise and approach parity. The administration of the program will be decentralized as much as possible through local machinery already established for wheat adjustment.

RESEARCH

The principal function of this Department is scientific research. All its other activities, such as weather and crop reporting, the eradication or control of plant and animal diseases and pests, the administration of regulatory laws, highway construction, and economic guidance, are the practical expression of research results. Research is the primary thing, the keystone of the entire structure of the Department's functions and services. Naturally the Department does not rely exclusively on the findings of its own investigators; on the contrary, it draws upon the general fund of scientific knowledge as it increases throughout the world. But this is one of the tests of its scientific efficiency and value. Were the Department not engaged itself in creative scientific work, it could not use creatively the findings of other institutions. Only science can assimilate science.

All-pervasive as research obviously is in the sum of the Department's activities, we may yet fail to grasp this fact in its full meaning. This may happen if, for theoretical convenience, we separate the work into watertight compartments, and strike off boundary lines that have no counterpart in nature. Commonly, for example, we think of science as restricted to chemistry, physics, and biology, and exclude from it certain problems in economics, politics, and sociology. We distinguish improperly between the exact and the inexact studies. There is really a difference only of degree. Science, we say, has given us the means of plenty, and now social organization must show us how to use this instrument. Actually, science has not given us the means of plenty until it has solved the economic and social as well as the technical difficulties involved. The field of science is social as well as technical and includes the human application as well as the discovery of scientific facts and principles. The scope of science is life as a whole, and not just certain limited aspects of life.

Agricultural science furnishes many illustrations of the principle. Research has developed many new uses for farm byproducts, the commercial development of which often requires large-scale operations for a wide demand. Practical benefit depends, therefore, on the collaboration of the production specialist and the chemist with the industrialist and the industrialist with the consumer. Chemical discoveries in refrigeration, in the preservation of fruits and vegetables by heat treatment, and in canning affect types of farming, the geographical distribution of farm enterprises, and the national dietary. Economic research discloses the powers and limitations of controlled marketing and controlled production and shapes national adjustment policy. Research in livestock diseases, besides directly safeguarding the public health, influences medical thought and medical practice. Discoveries in animal nutrition have a bearing on human

nutrition. As technology increases productivity, it compels attention to the distribution of products. The chemical analysis of foods and drugs is the primary means of food and drug law enforcement. Weather studies furnish warnings against floods and frosts and safeguard navigation and aviation. Single discoveries in science form part of a mosaic or pattern, the design of which is quite as important as the separate discoveries. Science is a living thing fashioned of many elements, each standing in a dynamic relationship to the whole and having no meaning apart from its place in the pattern. After the analysis of problems, by separate study, there must be a synthesis of the results, a synthesis which tends to grow wider and more comprehensive as the need develops for conceiving the application in terms of social welfare.

Research in this Department and in the agricultural experiment stations and land-grant colleges has been conducted for many years with these principles in mind. The research has developed structurally and functionally in adaptation to the continually changing environment. Certain difficulties, however, have tended to hamper free and full coordination of projects and to discourage certain basic studies. One drawback has been the allocation of research funds item by item, on a bureau basis, for objects sharply particularized. Under this system the research has been developed largely to meet emergencies, to throw up quick defenses against animal and plant pests and diseases, to solve specific economic questions, or to develop varieties or strains of plants and livestock suited to particular conditions. Research of this type, for objects well defined in advance, is extremely valuable, and will always be necessary. But it is not the only type of research which agriculture needs. In fact, such research is in the nature of superstructure. It needs much more foundation research to establish laws and principles. Science is exploration and should not be confined to territory that can be mapped in advance. One might as well equip an exploration party and forbid it to break new ground.

New Legislation for Research

As a step toward remedying this situation, Congress passed an act, which was approved June 29, 1935, making special provision for basic research in the Department, and in the agricultural experiment stations and land-grant colleges. The measure, now known as the Bankhead-Jones Act, also provides for the further development of agricultural extension work. Title I of the act authorizes and directs the Secretary of Agriculture to conduct scientific, technical, economic, and other research into laws and principles underlying basic problems of agriculture in its broadest aspects, and also authorizes and directs him to conduct research to improve the quality of agricultural commodities, to develop new and improved methods for their production and distribution, to discover uses for farm products and byproducts and manufactures thereof, and to study the conservation, development, and use of land and water resources for agricultural purposes.

For the purposes of title I, the act authorizes the appropriation of $1,000,000 for the fiscal year beginning July 1, 1935, and for each of the 4 fiscal years thereafter $1,000,000 more than the amount authorized for the preceding fiscal year, and $5,000,000 for each

fiscal year thereafter. This money is for work in addition to, and not in substitution for, research or other activities provided for otherwise. Forty percent of the money is for expenditure directly by this Department, and the remaining 60 percent for allotment among the States and Alaska, Hawaii, and Puerto Rico. Not to exceed 2 percent of the total may be used in administering the 60 percent available for the States and Territories.

Under title II the measure authorizes appropriations for the further development of the cooperative-extension system in the several States and the Territory of Hawaii. For this purpose it authorizes an appropriation of $8,000,000 for the fiscal year beginning July 1, 1935, and for each fiscal year thereafter an additional $1,000,000 until the total reaches $12,000,000 annually. This money will be distributed in a manner similar to that governing appropriations under the Smith-Lever Act of May 8, 1914, with the exception that the allotments will be made on the basis of farm population rather than of rural population, and with the further exception that the States and Hawaii need not match the Federal funds. Title II also authorizes additional appropriations for the land-grant colleges—$980,000 for the fiscal year beginning July 1, 1935, and the same amount for each year thereafter. This sum is to be divided equally among the several States and Hawaii. The same title authorizes $980,000 more for the colleges for the fiscal year beginning July 1, 1936, to be distributed to the States and Hawaii in equal shares, and $500,000 more each year thereafter until the additional amount reaches $1,500,000 annually. These latter sums are to be paid to each of the States and to Hawaii in the proportion which the population of each bears to the total population of all the States and the Territory of Hawaii. The maximum total for the land-grant colleges will, therefore, be $2,480,000.

Practical Aspects of Basic Investigations

In thus appropriating funds for basic research, in addition to funds for the study of highly specific problems, Congress recognized that fundamental research may often be more practical than short-cut research. Scientific history abounds with examples. Experimenters formerly attempted to control certain potato diseases by changing the time of planting the crop, by trying to keep the seed from "running out", and by adopting special methods of cultivation and fertilization. Fundamental research proved finally that filterable viruses could cause disease in plants. That one fundamental discovery furnished the basic knowledge for rational solutions of the problems of many diseases, not only in potatoes and other plants but in animals and human beings. Permanent solutions of many of these problems have been developed.

Certain fundamental studies at agricultural experiment stations and elsewhere have disclosed some of the effects of rations derived from various plant sources and have led to exact knowledge about vitamins. This in turn answered many specific farm problems, such as the real difference in feeding values of white and yellow corn, the value of pasturing livestock, the value of well-cured hay, and other problems which had been perplexing investigators.

Fundamental research into the chemical make-up of fats, sugars, and proteins showed why certain things serve as foods and to some

extent why they are good foods or poor. Investigations in the chemical constitution of proteins revealed that they consist of a small number of comparatively simple substances joined together. These substances are called amino acids. Digestion breaks down the proteins into amino acids, which the animal body absorbs and rebuilds into proteins. Hence the food value of a protein depends upon how easily digestion breaks it down, and into what amino acids it is resolved. It has been demonstrated that some of the amino acids are essential to the health of the animal while others are not. With this knowledge it becomes possible to define with more scientific accuracy what is a proper food. Studies in the conversion of sugar into alcohol by fermentation reveal that the process may be modified to yield glycerin instead. Glycerin is a necessity in war, and its production from sugar influenced the course of the World War 20 years ago. It is a truism, however, that the value of scientific knowledge depends on the use we make of it; and the progress of science doubtless promotes more good will than ill will among the nations.

Weather Forecasting

Long-range weather forecasting is a basic problem which should be more studied. Meteorological data are available from many stations located in the larger land areas as well as from many more or less isolated islands. Investigators have found weather relations in some cases direct and in others inverse between points widely separated on the earth's surface, and there is every indication that these are bound up in some way with the general circulation of the atmosphere. It appears, too, that the so-called centers of action or semipermanent areas of high and low pressure change their positions and intensities from time to time. The shift in position may be so marked that certain regions which normally are within a high-pressure area may change to a low-pressure area or may change from one side of a low- or high-pressure area to the opposite side. The result is to change the character of the weather from hot to cold or from dry to wet. Meteorologists believe it would be fruitful to determine whether these changes of position and intensity of the centers of action can be related to changes in the temperature of the ocean, changes in the polar icecaps, or changes in solar activity, as well as whether a change in the position and intensity of one center of action is followed by changes in other centers. There is something in common in the weather in widely separated parts of the earth, even in countries on opposite sides of the globe. Changes in rainfall in central North America show a general similarity to changes in central South America. Changes in pressure in southern South America during September, October, and November show a general relationship with the subsequent May to September monsoon rainfall in India. Such relationships are undoubtedly associated with the general circulation of the atmosphere and the behavior of the so-called "centers of action." Thorough investigation of such associations as they affect the weather in the United States would be profitable. Foreknowledge of the weather, such as would make it possible, for example, to predict droughts, would obviously be of enormous practical value, not merely in revealing factors which control variations in crop yields but in the regulation of all kinds of economic activities.

Fragmentary and piecemeal research in problems which are essentially basic almost necessarily yields disappointing results. Plant breeders, for example, may develop a sugarcane that resists mosaic disease, only to find that the new strain falls an easy prey to diseases that the older varieties resist. It is obviously necessary to study the fundamental nature of resistance to disease. Entomologists, under the pressure of emergency demands, may try to discover an insecticide that will kill a particular moth and save a particular crop, and the effort may be worth while. It may be still more important, however, to reveal the habits and physiology of insects in general, so that the control problem can be dealt with broadly as it applies to many insect pests. Fundamental chemical research on the properties of insecticides may solve many insect-control problems simultaneously. Research for limited, so-called practical objects often fails, until scientists widen the scope of their inquiry to include the basic elements involved and so reveal the governing laws. In this way they discovered that resistance to disease is a genetic character, the factors for which may be inherited. This discovery has already borne much fruit and ultimately will mean more than innumerable attacks on specific plant diseases.

Main Goals in Basic Research

As knowledge widens, it touches the unknown at more points and raises new problems; and it is easy to pose more questions than can be solved. The fact that we glimpse a big problem is not in itself a sufficient warrant for spending time and money in an effort to solve it. There should be a fair chance of progress. Authority for this Department to conduct research without being required to tell in detail what it expects to find, does not justify aimless wandering or imply that a sense of direction is unnecessary. Fundamental research need not be less practical than research for concrete specified advantages, though we may be unable to foresee just where it will lead. The analogy with geographical exploration is apt. Explorers do not strike out into a void but into territory which they want to know better. Similarly, the scientific investigator has a general idea of the continent he wishes to map, and perhaps also a rough notion as to its main contours. He may not move straight to a defined objective; but the method of fundamental research is not impractical merely because it may be indirect. On the contrary, the indirect approach may be the better way, just as it is better to catch fish indirectly with rod and line rather than directly with bare hands. Heretofore, the endowed scientific institutions such as the great foundations and some of the universities have been freer to conduct research of this character than have public agencies. Increased fundamental research in the Federal and State agencies is timely, and in full accord with the principle that these public institutions should be prepared to keep our basic knowledge abreast of our need in meeting definite human problems.

The Trace-Elements Problem

An example of a practical question that is truly basic is the role of the various chemical elements in plant growth. Both animals and plants contain in their structures, in varying quantities, practically

all the known chemical elements, and it may even be that all these elements are essential. Scientists no longer believe, as they did until quite recently, that only 10 elements are necessary to crops and that application of the 3 important elements, nitrogen, phosphorus, and potassium will solve most fertility problems. They have discovered that magnesium, iron, or sulphur are lacking in some soils and that in some regions certain of the less common elements such as boron, iodine, copper, or manganese may not be present in quantity sufficient for proper plant nutrition. Even less common elements, such as chromium, strontium, titanium, and caesium, may have functions in plant growth. A deficiency of certain elements in the soil may mean the difference between profitable and unprofitable farming, or between desirable and undesirable products. An excess of a given element such as boron or selenium may prove to be decidedly harmful. It is imperative to know what elements are important in plant nutrition; for a shortage in the soil means a lack in the plant, and consequently in the livestock that feed on the plant. This is believed to have important effects on human nutrition.

Investigation of the so-called trace elements in foods would begin with a soil or medium of known chemical constituents, and continue with studies in nutrition. The task would require the cooperation of agronomists, chemists, and animal husbandmen. It would call for experiments in the production of food plants under controlled conditions, so as to determine how they behave on different soils. Investigators would observe the effect of the presence or absence of elements such as calcium, iron, copper, iodine, fluorine, and boron on growth, yield, and reproduction. Likewise, they would study the influence of elements known to be often detrimental, such as selenium, fluorine, and boron. Some experiments would require an abundance, others a shortage, and still others an entire lack of a particular element in the soil. The next step would be the feeding of experimental animals. Food material obtained under the controlled conditions would give results measurable in animal metabolism, growth, glandular activity, and disease conditions.

The Role of Enzymes

Much remains to be learned about enzymes—the ferments produced by the vital activities of living cells. Study of their action as it appears in the cellular processes of respiration and metabolism, oxidation and hydrolysis is essential to the solution of many agricultural and industrial problems. Among these problems are the utilization of enzymes in food, beverage, chemical, and other industries; the destruction of the enzymes that cause agricultural products to spoil, the function of enzymes in the curing of hay and the fermenting of silage; the employment of enzymes in the analysis of agricultural products; and the preparation of enzymes for medicinal use. The generally important result to be expected from enzyme chemistry is the explanation of many physiological processes, as mysterious now as was digestion—an enzyme process—a hundred years ago. Very lately the mechanisms of fermentation and respiration have been partly worked out in this way.

Research in the Department has dealt already with some aspects of the role of enzymes, as, for example, the deterioration of stored

eggs and the fermenting of dough for breadmaking. Other problems in which enzymes seem to play a significant part have been little studied. What substances in sweetclover inhibit the blood-clotting mechanism and cause animals to become bleeders when fed sweetclover hay? What relation, if any, have enzymic processes to the premature sterility of livestock? What are the enzymic reactions that constitute the processes of ripening in fruits, in grains, and in meats? These are typical questions about enzymes, the answers to which would be tremendously useful, but which cannot be answered without more fundamental research.

Genetics

The development of superior plants and animals through breeding is one of the great achievements of American agriculture. Although progress in the science of genetics has been exceedingly rapid since the rediscovery of Mendelism in 1900, progress in the art of breeding has been relatively slow. This is particularly true in animal breeding, where the value of individual units is very high and reproduction is relatively slow. Nevertheless, livestock breeders have relied increasingly on the science of genetics and as a result they have abandoned many false doctrines and eliminated much unnecessary work. Yet there remains entirely too much guesswork in the prevailing breeding practices, and there is great need for additional research in genetics and related fields, particularly in regard to the nature and inheritance of animal characters of economic value.

Much research in genetics has been done with organisms of little economic value such as *Oenothera*, *Datura*, *Drosophila*, etc. Although this work has been invaluable in establishing certain laws of inheritance, its practical value depends on the application of these laws in the production of agriculturally important plants and animals. Progress in genetics since 1900 has demonstrated such fundamental concepts as the occurrence of linkage groups and the futility of selection within pure lines. If the art of breeding is to be materially improved, however, it is necessary to have more basic information on such matters as the mode of inheritance of important characters, the nature of resistance in plants and animals to disease and insects, linkage groups, and the cause of exceptional vigor in hybrid strains.

Perhaps much of this needed information can best be supplied by better coordination of research effort, similar to that which has produced such exceptional results with corn. In 1928 corn geneticists initiated a systematic study in which each of the 10 chromosomes of corn was assigned to workers in different institutions. This coordination of effort has eliminated much possible duplication and has speeded up the research program to a remarkable extent. Similar cooperation for other economic plants and for certain kinds of livestock is highly desirable as fundamental research in genetics is pressed forward.

Chemical Photosynthesis

In chemical investigations the photosynthesis of plant substances furnishes an outstanding example of a fundamental problem, which, to be sure, is inherently very difficult. Nevertheless, basic research in it may lead indirectly, in ways not now foreseen, to im-

portant agricultural and industrial results. Through the radiant energy of the sun, plants transform carbon dioxide and water, with the aid of a chlorophyll and other related pigments, into carbohydrate material. This is the primary product of photosynthesis. Subsequent transformations convert the first product into fats, proteins, terpenes, alkaloids, flavors, and pigments, which are in the widest daily use. Chlorophyll is the most important coloring matter in the vegetable kingdom, and the role of chlorophyll in photosynthesis is still largely unknown. It takes approximately 100,000 calories of energy to produce an ounce of sugar from carbon dioxide and water, and yet plants produce many ounces. We do not know how they perform this miracle, nor how they operate their factories without using enormous pressures, high temperatures, expensive chemicals, and elaborate equipment. This mystery shrouds the basic problems of all life on the earth. Other phases of photosynthesis which deserve consideration are the effect of light on ripening processes, on the chemistry of seed germination, on the development of color in flowers, on rancidity in food products, and on vitamin-containing products such as ergosterol.

Research in Farm Economics

Besides authorizing additional basic research, the new law provides, as already noted, for research regarding the production, distribution, and consumption of agricultural commodities. In other words, it authorizes the study of essential elements in farm adjustment. This is largely a problem in the coordination of research procedures and research findings, a task necessarily difficult under the itemized project method whereby different governmental bureaus with separate funds and separate projects operate more or less independently. The new legislation affords the Secretary greater opportunity to organize a joint attack on this and similar problems—to bring the soil chemist, the agronomist, the animal and dairy husbandman, the agricultural engineer, and the economist into a more effective collaboration on problems within the scope of the act. The coordination of different studies is often essential in basic investigations, and yet difficult with funds appropriated for highly specialized work. Sometimes, for example, the problem seems to be quite definitely in the field of chemistry, as in one case where certain stains in wood seemed to be of chemical origin. Later the stains proved to be due to an organism. It was then necessary to enlist the cooperation of the biologist. Many problems require the cooperation of chemists, physicists, and bacteriologists before their fundamental nature can be revealed. The necessary coordination of studies should be facilitated under the new law.

Flexibility in Procedure

Still another advantage of the new law is the flexibility it authorizes in research procedure. Heretofore the Department has had only limited authority to shape or change the course of its investigations in accordance with changing requirements. Facts learned in the course of an investigation may open new possibilities, or even suggest the abandonment of projects as they were originally conceived. Knowledge gained in one field may greatly influence studies in an-

other. Rigid procedures, which make small allowance for this fact, and which permit no change in the marching orders, are very hampering. With all research funds appropriated item by item, more than a year must pass after research plans are made before the funds become available. Another delay occurs if circumstances necessitate a change of plans. This lack of elasticity in the shaping of research programs sometimes frustrates their purpose. Generally the method of itemized appropriation works well. Research projects do not need to be changed radically very often. The exceptional cases, however, may be extremely important. It may sometimes be vital to conduct an investigation uninterrupted, even if an important change in its direction becomes advisable. Henceforth it will be easier for the Department to meet such exigencies. On approval in writing by the Secretary, funds provided for special research in this Department under the new law may be made available for the prosecution of research previously instituted or for the prosecution of new research. In short, the legislation authorizes a flexible attack on research problems and permits the Department to reshape old projects and to initiate new ones as occasion may require.

ANIMAL INDUSTRY

Recent contributions of research and the application of veterinary science have exerted a steadying influence on stock raising and agriculture. The hog raiser, for instance, who immunizes his herd against hog cholera and who also uses the system of swine sanitation developed by the Department, operates under a better and safer economic system that was possible before research provided these forms of protection. Ability to control stomach worms, scab mites, and other parasites of sheep likewise have placed the production of that class of livestock on a more secure basis. Still further results of coordinated research and its application have been industrial developments such as the manufacture of biological products, dips, and disinfectants.

In the breeding of domestic livestock the Department has made available to livestock owners knowledge of Mendelian inheritance and other basic breeding principles. Supplementing former studies showing the greater utility value of improved livestock over ordinary types, the Department has conducted record-of-performance investigations with the principal species of domestic animals. Individual beef steers of different breeding have required from as little as 373 days to as many as 533 to reach a finished weight of 900 pounds. In the case of other animals, data on the rate of gain have shown similar variations that may be attributed to inherited characteristics. Since rapid development of animals contributes to profits in stock raising, record-of-performance studies are a means of identifying breeding animals of superior merit.

Bovine Tuberculosis Reduced to 0.6 Percent

An outstanding achievement in establishing healthy foundation herds of cattle has been the extensive aggressive compaign against tuberculosis. Through the detection and slaughter of diseased cattle, including beef as well as dairy types, cooperating Federal and State officials not only have checked the spread of this

disease but have reduced its average degree of prevalence from 4 percent in 1922 to 0.6 percent in 1935. This is the most extensive veterinary field campaign conducted in any country at any time.

In the face of much doubt as to the feasibility of the undertaking because of the vast numbers of cattle, their extensive interstate shipment, their constant perpetuation by breeding, the expense of the campaign, and the problem of obtaining a sufficient number of trained inspectors, this work, begun in 1917, progressed steadily until 1934. At that time it received renewed impetus through funds made available by the Agricultural Adjustment Administration. In the spring of 1935 nearly 100,000 cattle were being tuberculin-tested daily. Systematic testing of all cattle in 73 percent of the counties in the United States, together with the removal of animals found to be tuberculous, has already been accomplished. An all-time record in volume was set during the fiscal year 1935, when more than 25,000,000 cattle were tuberculin-tested.

From both public-health and agricultural viewpoints it is noteworthy that tuberculosis eradication, since the beginning of the cooperative campaign, has resulted in the detection and slaughter of more than 3,000,000 tuberculous animals. The cooperation received from livestock owners has been highly satisfactory in almost all the localities where the work has been conducted. The emergency funds allotted by the Agricultural Adjustment Administration have hastened this work materially in certain States. Such funds made it possible to pay indemnity to owners of reactors in cases where no State payment could be made because of lack of State funds or lack of authority to pay under the State law.

Thus the work has extended into many States where it could not have been done with the means provided for the regular tuberculosis work. The total payment that the owner received for his reactors from all sources did not exceed, however, the amount he would have received if the payment had been made from regular Federal and State funds.

Department Helps Cattle Owners Combat Bang's Disease

Within the last year the Department has likewise satisfied the appeals of dairymen, in particular, and cattlemen, in general, for assistance in suppressing the costly and insidious malady known as Bang's disease or infectious abortion. In the past this disease has taken a toll from the livestock industry estimated at $50,000,000 a year. The infection not only caused death of calves and impaired production in the herd, but was a serious handicap in the sale of breeding stock. Many States have restrictions against the entry of animals from infected herds. A further disturbing element was the close relationship between Bang's disease in cattle and undulant fever in man. Considerable evidence indicates that raw milk from a herd so infected may transmit the organism, *Brucella abortus*, from cattle to man.

Federal Aid In Controlling Mastitis

As a further step toward a more effective control of animal diseases, the Department has undertaken, as a part of the emergency program in behalf of agriculture, to aid cattle owners in suppressing

mastitis, an udder disease affecting principally high-producing dairy cows. The plan of procedure, put into effect in January 1935, provides for physical examination of cows by qualified veterinary inspectors. The plan is voluntary on the part of cattle owners. Cows with marked cases of mastitis are eliminated, and the owner receives a Federal payment limited to a maximum of $50 per head for purebred cattle and $20 for grades. The owner receives the salvage and agrees to follow official directions for controlling the disease in his herd. He must also participate in the program for controlling Bang's disease.

During the first 6 months of the mastitis-control plan, approximately 3,800 owners submitted their herds to inspection. Of 94,919 cows examined, about 12 percent were found to be marked cases, 2 percent were classed as suspects, and the remainder were apparently free of mastitis. These figures are considered representative chiefly of dairy herds in which mastitis is known or suspected to exist and whose owners are anxious to eliminate it. The extent of the disease throughout herds in general is thought to be very much less.

Activities in Behalf of the Poultry Industry

Federal legislation, approved by the President August 14, 1935, requires that dealers in live poultry, in cities to be designated by the Secretary of Agriculture, must obtain Federal licenses and conduct their business under the type of Federal supervision already governing the marketing of other livestock. The new provision is an addition to the Federal Packers and Stockyards Act and is designed to prevent excessive charges and unfair and deceptive practices and devices at certain markets where live poultry is sold in large volume. Expected benefits include the reduction of excessive handling costs, thereby permitting better returns to producers and more reasonable retail prices to consumers.

In the commercial egg trade, certain markets discriminate against eggs having so-called "tremulous" air cells, this characteristic signifying that the cell, instead of being fixed in its normal place, has some movement and in extreme cases may even be free within the shell. The condition has been observed frequently in eggs shipped considerable distances, with the result that producers who depend on distant markets have been at a disadvantage. Experimental study of the condition has involved the shipment of eggs for distances up to 2,400 miles, with various types of packing, both loose and rigid. The data indicate quite conclusively that packs in which the eggs are held firmly result in fewer tremulous air cells than loose types of packing. Briefly, the condition can be eliminated to a large extent by the use of rigid-type packs.

CHEMISTRY AND SOILS

In this period of extraordinary turmoil the research and service branches of the Department, equally with the economic and adjustment sections, have profound readjustments to make. The character, magnitude, and direction of these readjustments depend largely on agriculture's changing technical requirements.

Extensive crop shifts to meet altered market conditions involve correspondingly extensive modifications in farm practices, particu-

larly in regions faced with the necessity of developing new sources of cash income. As production for export declines, areas that formerly specialized heavily therein must grow things that can be sold at home. They must regulate the amount, the kind, and the quality of their production differently. For example, the decline of our wheat exports creates new technical problems for the wheat areas. It obliges wheat growers to put more of their land into grass and forage and to go more into mixed farming. They cannot fully adapt old techniques to the new requirements. Crops, tillage methods, and farming systems useful elsewhere may not entirely suit the formerly specialized regions.

On the other hand, practices once efficacious in the regions not directly concerned in the export trade may become less efficacious as the agricultural pattern changes. Broad shifts from intensive to extensive types of farming affect our agricultural economy as a whole and create new technical as well as new economic problems for farmers in all parts of the country. Should it be necessary for the South to raise more corn and hogs, the Corn Belt will have to raise less, and the resulting readjustments in the Corn Belt will have repercussions on the dairy regions and on the range States. Technical knowledge cannot entirely eliminate but it can lessen the resulting regional conflicts, provided it fits the new requirements with adequate local precision. In short, the farm crisis is technical as much as it is economic and makes calls as urgent upon the chemist, the animal husbandman, the plant scientist, the soil scientist, and the agricultural engineer as it does upon the economist.

Findings of the Soil Survey

The Department has been fully conscious of these truths and has shaped its research accordingly. In the Bureau of Chemistry and Soils, for example, it has put increased emphasis on the investigation of soils as a basis not only for crop adjustments and crop shifts but for the conservation of soil and soil fertility and for guidance in land planning. Formerly, the Division of Soil Survey particularly studied methods of soil classification and worked out details for locating the boundaries of soil types on base maps. Knowledge thus gained enabled it to help immediately in dealing with the land-adjustment problems that became acute following the depression.

It has now mapped about half the nonmountainous portion of the United States and has covered much of the mapped areas by detailed surveys. On the greater portion it has completed surveys on a scale of 1 mile to the inch and has prepared maps showing in great detail the distribution of soil types and other physical features of the land. For nearly all regions it has sufficient information for general recommendations regarding land use and has completed a general soil map of the United States giving undoubtedly the best and most detailed presentation ever published of a country's land resources.

Fertilizer Studies

Farm earnings are the result of three variables—volume, prices, and costs; and the relative importance of these factors changes from time to time. During the first years of the depression it was proper

to emphasize volume and prices because surpluses and low prices were the outstanding facts in the agricultural situation. Nevertheless, costs did not cease to be important, and the Department continued to study ways and means of reducing them. The fertilizer problem provided a significant opportunity.

As farm returns decline, a dilemma arises for the farmer who desires on the one hand to cut down his expenses and on the other hand to increase his yield per acre. What he can afford for fertilizer depends partly on the prices obtainable for agricultural products and partly on the cost and utility of fertilizer materials. When costs threaten to exceed returns anyway, the incentive to use fertilizer drops almost to zero. Few farmers sufficiently appreciate the merely negative advantage of reducing their losses. With price recovery, the incentive revives, but it will not be strong until the returns from applications of fertilizer demonstrably exceed the cost. In such circumstances efficient farming depends tremendously on the extent to which economies may be made in the purchase and use of fertilizers.

In recent years fertilizer developments largely initiated by the Department have reduced the cost and increased the usefulness of fertilizing materials. Formerly the raw materials for preparing commercial fertilizers came only from mineral deposits and waste products and had a low plant-food content. Mixtures from such materials were of low grade. There were no economical methods for preparing higher analysis mixtures. Research in the Department aided fertilizer manufacturers to obtain nitrogenous material of high plant-food content from the atmosphere at a lower cost than from any other source.

Other studies indicated how potash salts may be enriched at a cost substantially less than the savings in bags and freight and developed improved methods for preparing phosphatic materials of higher plant-food content. This Department developed the electric-furnace method, which the Tennessee Valley Authority is testing on a quantity-production scale. The final product has all the constitutents of ordinary superphosphate, and more than twice as much plant food.

Full utilization of these improvements awaits a more general recognition of the fact that fillers, if put into mixed fertilizers to the customary extent, add unnecessarily to the retail cost. As yet, the new methods have not caused a marked increase in the average plant-food content of commercial mixed fertilizers, though they make possible the preparation of mixed fertilizers that have double the plant food of the average mixed fertilizer. The reason is that the use of fillers has increased almost proportionately with the use of the improved fertilizer constituents. Fillers constitute 20 percent of the average cotton fertilizer in certain Southern States.

That great savings would result from the elimination of filler and from the elimination of organic matter and of side dressing, when these changes would not affect the strength of the fertilizer, appeared from a study of the open price schedules prepared by fertilizer manufacturers under the National Recovery Administration Fertilizer Code. This study showed that a reduction of even 50 percent in the wholesale cost of the nitrogen, phosphoric acid, and potash materials in mixed fertilizers would reduce the retail cost only 9, 8, and 3 percent, respectively.

On the other hand, the analysis indicated that the elimination of filler, the elimination of organic matter with the discontinuance of the practice of side dressing, and the use of double-strength mixtures would effect a saving in the retail cost of 8, 15, and 22 percent. By using higher analysis fertilizers and by adopting approved changes in fertilizer practice, the farmer can use fertilizer profitably under circumstances that would otherwise forbid such action.

New Uses for Crops and Byproducts

Farm adjustments necessitated by the loss of foreign trade emphasize the importance of developing new uses for crops and crop byproducts. The Department has appointed a committee of scientists from several of its bureaus to study the research now being done in this field and to indicate promising new lines.

At present the farmers have profitable uses for only about half of what they grow. The other half they must either throw away or turn to some relatively low-yielding use. For each pound of corn or wheat marketed the farmer discards about a pound of fodder or straw. Fruit and vegetable growers grade out a good percentage of their crops as culls and lose part of the crop as peelings and seeds. Chemists strive constantly to find ways of utilizing these wastes.

But the task is full of difficulties. Here again the technician and the economist must collaborate. Chemical research may develop methods that cannot be used in the prevailing economic situation or with existing manufacturing facilities. The successful economic use of new methods may require quantity production for an enlarged market and may necessitate economic research as well as commercial experimentation. Nevertheless, each year sees progress in the commercial application of the Department's research in the utilization of farm crops.

An example is the utilization of sweetpotatoes in manufacturing starch. Sweetpotato growers usually have to grade out a large percentage of their crop as culls; in fact, the culls may run as high as 30 percent. Though livestock consume part of the culls and though some find a market in the canning industry most of the culls have to be sold at a loss. The Department's chemists discovered how to make from sweetpotatoes a satisfactory starch to be used as sizing for stiffening and putting gloss on textile goods.

The most difficult problems in this task were getting rid of the yellow color in sweetpotatoes and developing an efficient manufacturing method. Scientists in the Department overcame the first difficulty and tackled the cost problem on a factory scale in a demonstration factory in Mississippi.

In the utilization of straw, hulls, corn stover, and so on, the problem is often to find uses more profitable than the present uses. These byproducts are worth something as feed in many parts of the country and are not always strictly waste materials. The problem is to determine whether corn stover, for example, will bring higher returns manufactured into fiberboard or into cattle feed. Some factories are making and selling large amounts of insulating board made from cornstalks, straw, and sugarcane bagasse. There is a wallboard made from cornstalks which can be used instead of plaster or as a subsiding or as a subflooring. One factory is already making this product. Its

future depends on the relative cost, as compared with that of other materials, and that, in turn, depends largely on the quantity that can be sold.

It is well not to lose a sense of proportion in considering the industrial utilization of farm products and byproducts. Some enthusiasts, fired with extravagant hopes generated by a few successes thus far attained, believe that agriculture should aim primarily at supplying raw materials for the manufacture of industrial goods and should relegate its job of feeding and clothing the race to a secondary place. Such a change of emphasis, though not inconceivable, would necessitate prodigious technical progress, as well as an enormous increase in the spending power of the average consumer.

The direct need for food and clothing will constitute the main agricultural demand in any future that we can foresee, even if the population remains stationary or declines. Technical progress may enable agriculture to satisfy this demand with relatively less than the effort now required and to make some agricultural land and labor available for other objects. It is not likely to revolutionize completely the relationship between the farm production of food and clothing fibers and the farm production of other things.

We can give full recognition to the advantage of growing crops for industrial uses and of salvaging agricultural surpluses and wastes without assuming that the " tail has already begun to wag the dog."

FOOD AND DRUG LAW ENFORCEMENT

In the field of food and drug law enforcement, regulatory activities have paralleled congressional consideration of the proposed new food, drug, and cosmetic legislation, described in some detail in the last annual report. Senate 5, a bill—

> to prevent the adulteration, misbranding, and false advertising of food, drugs, devices, and cosmetics in interstate, foreign, and other commerce subject to the jurisdiction of the United States, for the purposes of safeguarding the public health, preventing deceit upon the purchasing public, and for other purposes—

passed the Senate on May 28, 1935, and is now in the hands of a subcommittee of the Committee on Interstate and Foreign Commerce of the House of Representatives. This measure retains the meritorious features of the present Food and Drugs Act and provides added consumer protection in the way of control of cosmetics and curative devices, and of advertising. With the addition of a few essential amendments which the Department has recommended, the proposed new law will unquestionably constitute a far more effective agent for public protection than the present statute.

It has frequently been asked why a law like the Food and Drugs Act should be enforced in the Department of Agriculture. There are logical reasons for it. The food supply, and, to some extent, the drug supply, are largely products of agriculture. Nowhere outside the Department of Agriculture is there obtainable more comprehensive information about food production, composition, and manufacturing processes. No other department has so many bureaus whose related facilities can be utilized in effecting corrections of unsatisfactory conditions. This is illustrated nowhere better than in the vexing problem of spray-residue control wherein the Food and Drug Administration has exercised restrictive action under the

terms of the law against shipments of fruits and vegetables containing toxic spray residues. The Bureau of Plant Industry has studied and developed procedures for removing excessive residues from fruits and vegetables; the Bureau of Chemistry and Soils has sought to develop effective substitutes for objectionable poisonous sprays, and the Bureau of Entomology and Plant Quarantine has cooperated in formulating rational spray schedules designed to give the maximum protection to the crops with a minimum of poisonous spray remaining at the time of harvest.

It is a foregone conclusion that a regulatory organization like the Food and Drug Administration which is called upon in its law-enforcement operations to confiscate large quantities of adulterated food and drug products and prosecute the responsible shippers will be subjected to bitter condemnation by the individuals against whom the actions are directed. Sometimes, moreover, criticism comes from groups who claim to represent the consuming public and who assert that enforcement operations are inefficient and that the Food and Drug Administration is indifferent to the public welfare and shows undue solicitude for the producer and manufacturer of food.

Seizures and Prosecutions

Trade complaints, however, originate almost exclusively among that small minority of producers or shippers who traffic in illegal foods and drugs. The majority are dealing exclusively in legitimate products and recognize that strict enforcement constitutes not only essential consumer protection but an important barrier against the unfair competition afforded by adulterated and misbranded products. As to the assertion that the Food and Drug Administration is indifferent to consumer welfare, the record speaks for itself. It shows that in the course of the fiscal year the Administration examined more than 60,000 foods and drugs. It initiated action in connection with more than 3,000 consignments, including over 2,000 seizure actions and over 1,000 prosecutions.

This record does not include over 200,000 specimens of cream from interstate and intrastate sources which were inspected in cooperation with State and municipal officials, with some 8,000 condemnations. It inspected more than 35,000 importations of foods and drugs, of which approximately 10 percent were excluded because of adulteration or misbranding. In connection with spray-residue activities alone, it examined over 6,000 samples of fruits and vegetables and instituted 338 seizures. In addition to its regulatory actions on this project it worked constructively with State authorities and growers' associations in an endeavor to assist them in so regulating packing and shipping operations within the various States as to guarantee effective cleansing, through voluntary action of the industry under State supervision.

Research in Food and Drug Law Enforcement

In the early years of the Food and Drugs Act the enforcement staff had to cope with innumerable types of adulteration. Many of them were crude and easily detected by any chemist, though technical knowledge in this field was meager. Faced with prosecution, adul-

terators refined their methods; it became evident that the Government chemists would have to move fast to keep up with the lawbreakers. Soon the multiplicity of new products and the industrial application of science made it indispensable in the administration of the statute to carry on extensive research. It was necessary, moreover, that the research results should be as nearly as possible unchallengeable, as the findings were practically certain to be vigorously attacked in the courts.

Accordingly a research staff was organized to study the identity, composition, preparation, and storage of foods and drugs by objective methods, so as to establish a basis for judging whether products offered for sale complied with the law. Though frequently intricate and difficult, the investigations are necessarily limited in type and scope. They seek to show whether products are injurious to human health, whether they contain filthy or decomposed material, and whether their character or their labeling cheats the consumer. The objective is consumer protection. Within this relatively narrow field, the nature of the work imposes certain conditions. It is important, for example, to have quick and simple methods for determining health risks, because the law requires that offending articles be intercepted in interstate commerce. Leisurely investigations will not do when dangerous products must be removed from trade channels.

Also the necessity of covering the entire United States makes it difficult to use costly or intricate apparatus in all cases. Finally, the investigational results must be such as to convince laymen, for judges as well as juries are laymen in this field. Moreover, the results must be convincing also to manufacturers who wish to comply with the law and to turn out goods free from harmful characteristics. Findings very significant to highly trained research workers may not look significant at all to the nontechnical mind. Yet in spite of these necessary limitations, research in the Food and Drug Administration puts effective barriers in the way of law violation and assists reputable manufacturers in fulfilling the law.

Important Byproducts of Research

Sometimes the scientific work of the Food and Drug Administration yields important byproducts. Formerly, for example, many manufacturers of tomato products did not eliminate rotten tomatoes by sorting and trimming. Anyone can detect rot in whole tomatoes; but after the manufacturing process, which reduces the product to fine particles and strains and seasons it, the problem becomes infinitely more difficult. In the worst cases, changes in the characteristic acids in the tomato furnished evidence; but a real clean-up demanded more direct and reliable indications.

The problem was solved not by chemistry but by the microscope. Examining hundreds of samples of decaying raw tomatoes, and of catsup and of puree made from similar material, observers noticed that the rotton areas were really masses of microscopic mold filaments, and that the number of these mold filaments in the finished products correlated surprisingly with the percentage of rot in the original tomatoes. This method of detection appealed immediately to the manufacturers and distributors anxious to turn out and handle clean tomato products and simplified the task of the law-

enforcement agency. It enabled the plant microscopist, by an examination requiring only a few minutes, to tell whether the sorters were doing their work properly. The mold-count method is now in practically universal use in plant control, and in the purchase of tomato products on specification. It is successful also in testing many other food products that tend to become unfit for use chiefly through the action of molds.

Recently the Food and Drug Administration developed improved methods for the determination of inorganic poisons in foods, and the beneficial results promise to be extremely far-reaching. Some years ago, growers and shippers adopted a fruit-washing technique, devised in the Department and protected by a public-service patent, to reduce the lead arsenate spray residue on their products. Later a supposedly improved procedure was adopted by the industry. But the new method removed the arsenic more efficiently than it removed the lead, and a determination of the amount of arsenic that remained no longer indicated approximately how much lead was still on the fruit. Up to that time analysts had measured directly only the arsenic content, because a reasonably accurate lead determination required 3 days—much too long a period for control measures to be used by the fruit industry or by regulatory officials. Adoption of the new fruit-washing system necessitated the development of a new control method, and research in the Food and Drug Administration met the need. Scientists devised a method satisfactory in precision, requiring only half an hour, and having the great additional advantage of permitting the practically simultaneous examination of several samples. The Department made the new method available immediately to the fruit industry, and its scientists gave first-hand instructions to specialists in industrial laboratories. In the fall of 1934 lead determinations by this method, in industrial and regulatory laboratories, totaled at least 100,000.

This development is only one among many happy results of the new analytical method. The power of this method to safeguard the public health extends potentially far beyond its application to the fruit industry. Physicians and toxicologists manifested interest in it, from such widely varying viewpoints as the treatment of cancer, the study of industrial lead poisoning, and the determination of the lead content of the American dietary from sources other than spray residue. Research workers sought applications of the lead-analysis method to all food products and to biological materials. Toxicologists wished to use it in gaging more accurately the risk to health involved in consuming minute amounts of lead. In like manner, research in the Food and Drug Administration concerning fluorine, another insecticide, promises to have broad indirect results as well as results directly beneficial to producers and consumers of farm products.

Study of Vitamins

Among the newer research projects of the Food and Drug Administration is a study of vitamins expressly to check the claims of commercial products. This is slow work. Chemical and physical tests furnish some help in the determination of vitamins in food products; but for various reasons the final determinations require the use of small experimental animals such as guinea pigs and rats.

Under certain conditions, some of the vitamins are unstable, and nutrition studies with such animals help to disclose what precautions must be taken to preserve the vitamins. This problem touches both the health and the pocket of the consumer in obvious ways; dependence on unreliable sources of vitamins may emphasize the truth of the old saw that a little knowledge is a dangerous thing. Aroused public interest in the subject of vitamins may be exploited to the disadvantage of the public in the absence of trustworthy tests of the vitamin content of advertised products.

Recent discoveries about vitamin D, for example, have raised certain questions regarding the clinical value of certain commercial products. The Food and Drug Administration has cooperated with the Children's Bureau in the Department of Labor in efforts to establish the relative clinical value of vitamin D as it occurs in cod-liver oil and vitamin D as produced artificially by irradiation of ergosterol. The Food and Drug Administration determined the vitamin D potency of cod-liver oil, and of irradiated ergosterol and prepared them for use. The Children's Bureau made the clinical investigations. Earlier studies by other investigators had indicated that larger quantities of vitamin D in the form of irradiated ergosterol were necessary to produce the same effect as a given quantity of vitamin D from cod-liver oil. This finding the joint studies of the Food and Drug Administration and the Children's Bureau did not confirm. On the contrary, the investigations, which included observations on 377 infants, provided certain evidence that a unit of vitamin D from irradiated ergosterol prevents rickets as efficiently as a unit of vitamin D from cod-liver oil. Such findings are obviously of first importance in checking the claims made on the labels of commercial products, and also in providing physicians with dependable clinical information.

Investigations in Bacteriology

Enforcement of the food and drug law also requires research in bacteriology. Food bacteriology furnishes data essential in determining whether or not foods are filthy, decomposed, or dangerous. Many types of filth in food can be detected without bacteriological examination; other types defy detection by other means. Filth consisting of waste materials from warm-blooded animals can often be detected only by bacteriological methods, and such filth, besides offending decency, is a serious menace to health. Progress in this field has closely followed that made in the study and control of communicable diseases. Methods developed in the Food and Drug Administration for the bacteriological examination of milk, water, shellfish, and more recently of canned foods, have thrown invaluable light on the significance of certain bacteria in food products.

It is particularly desirable to develop such methods, for determining bacteriological filth in foods commonly consumed in the condition in which they are produced, without further cooking. Fresh crab meat, picked by hand from the cooked crabs, packed in unsealed cans, and shipped in ice, is an outstanding example. This food is often produced under conditions which subject it to contamination. Investigations by the Food and Drug Administration some years ago, to ascertain the cause of food poisoning attributed to the consumption of crab meat, revealed grossly insanitary conditions

surrounding the preparation of this product in many factories. Though the Food and Drugs Act prohibits the interstate shipment of filthy food, it does not provide for the control of sanitary conditions in food plants. It was imperative, therefore, to develop a method for determining the presence of filth in the finished product, in a way that could be translated into terms of improper handling.

Analysis to determine the presence in crab meat of bacteria of the colon group was the method finally adopted. Excessive numbers of these bacteria in drinking water and in oysters have been accepted for years as evidences of filth and as signs of danger. Cooked crabs ordinarily do not contain any such bacteria. Consequently, their presence in the picked meat indicates that it has been contaminated, and this is the present basis for determining the fitness of crab meat for consumption. The technique adapts to crab meat, procedures that have been well established in the analysis of other materials, and indicates with reasonable rapidity the prevalence of fecal strains of bacteria. Its use serves both as a measure of filth in crab meat and as an index of the sanitary conditions surrounding its preparation. The result has been a marked improvement in these conditions. State control agencies and technological advisers to the crab-meat industry use the method constantly. Further research may develop similar methods for application to other products which are excessively handled and exposed to contamination. The field is wide. It must be entered with caution, however, because only a thorough knowledge of the production, handling, and distribution of such products can show the significance that should be attached to the presence in them of colon bacteria.

PLANT RESEARCH

The solution of problems related to crop production is a matter of years. The improvement of plants by breeding must extend through many generations. Varieties must be compared in a number of different kinds of seasons for correct evaluation. The same is true of tests of fertilizers, spraying practices, and cultural methods. To be productive, a program of plant research accordingly must be stable, with a concentration of effort until a given problem is solved or its solution found impracticable for the time being. Following such a program, the Department's plant scientists have continued to contribute to the efficiency of the plant industries and thereby to social and economic progress.

Perhaps nowhere is the importance of continued research better exemplified than in connection with diseases of forest trees. With the enormously expanded program of tree planting and conservation activities, the Department's pathologists have been under constant pressure for aid. In many cases the needed information was available through earlier research: in other cases, available information provided a background for rapid solution of new problems. Thus, investigations of the damping-off of pine seedlings in forest nurseries were begun in 1907 and have been continued since, as opportunity offered. Results available permitted decided immediate reductions in losses of seedlings in the extensive nurseries and also established a basis for rapidly developing simplified methods of control. Without this background of research far heavier losses would have occurred, and the whole program would have been seriously retarded.

Plant Breeding

The development of rust-resistant wheat varieties exemplifies well the importance of continuous research. The Ceres variety of wheat had an enviable record of yield, quality of product, and resistance to stem rust. True, it was known to be susceptible to some of the forms of rust, but these had not been important in the Dakotas and Minnesota on some 5,000,000 acres on which Ceres was grown. During 1934, however, spores carried by the winds from Texas and Oklahoma introduced forms of smut to which Ceres was not highly resistant, and yields of this variety were low. At the same time, the Thatcher variety of wheat, developed in cooperation with the Minnesota Agricultural Experiment Station, withstood the rust and produced satisfactory yields. The resistance of Thatcher is derived from durum wheat, and its combination with the good qualities of the common wheats in Thatcher represents a distinct forward advance. Hope wheat, developed from a hybrid with emmer, is even more highly immune than Thatcher. It is inferior in yield and quality, however, and its value lies in its use in further breeding efforts.

Grass Investigations

Since the beginning of farming in this country success or failure has to a large extent centered on knowledge of forage grasses and how to use them to the best advantage. Taking the grasses as a whole, there is no other group of plants so important and so vital to mankind. Besides the forage grasses used for meadows, pastures, soiling crops, range purposes, both open and in our great forest reserves, there are the food grasses, including all our great cereal-grain crops, industrial grasses such as sugarcane, and the vastly important group known as bamboos. The bamboos alone furnish food, shelter, clothing, household furnishings, and a multitude of domestic supplies for nearly a quarter of a billion people, mostly inhabiting the warmer parts of the Orient.

We are here concerned with forage grasses, forming the group indicated above and it is evident that we are moving, and moving rapidly, toward new frontiers of farming, where such grasses must play even more important roles in the fundamentals of agricultural practice than they have in the past. The forage grasses possess the needed attributes to act as "shock absorbers" in future efforts at balancing production, conserving our heritage, or what is left of it, of soil fertility, widening of opportunities for crop diversification, and opening new fields for plant and other industries.

Ever since the Bureau of Plant Industry was organized 35 years ago, it has done systematic work in taxonomic research, involving critical studies of all known native and introduced species and varieties of grasses in the United States. These studies have had to do largely with determining the botanical relationships of the different species and varieties and recording clearly defined scientific descriptions and geographic distribution, along with comments on habits, uses, and history of each species and variety. The results of this work have been set forth from time to time in various departmental publications, and within the past few months have culminated in the publication of an exhaustive and monumental Manual of Grasses

of the United States, in which are described 159 genera, 1,100 species, and 151 varieties now known to occur within our borders. Text figures to the number of 1,700 accompany the descriptions, the whole constituting a valuable, highly important, and necessary background or basis for future work in any of the new and specialized fields involving the utilization of members of this important group of plants. Soil-erosion experts, soil conservationists, specialists in farm management, plant breeders, and plant introducers will, it is believed, find this reference book highly useful and helpful in their respective fields.

Species and Varieties from Abroad

In the grass investigations so far conducted by the Department, those concerning the introduction of species and varieties from foreign countries have played an important part. It is interesting to note in this connection that practically all of our widely used grasses, constituting our chief reliance for meadows, pastures, lawns, golf courses, soil binding, and soil protection are immigrants introduced either accidentally or intentionally from foreign countries. The reasons for the success of introduced grasses as against our native species are not fully understood. The fact that this is the case would seem to point to further advantages that may accrue from careful and systematic efforts in searching the world for additional species, varieties, and forms. For 30 years or more plant scientists in the Department have made many explorations in foreign lands in search of new crop plants, including grasses. Several hundred species and varieties have been introduced, duly described in our official plant inventories, grown, tested, and distributed. Many species and varieties have also been acquired by correspondence through studies of botanical and agronomic literature of foreign countries.

A striking instance of the value of botanical knowledge of world flora is found in the introduction of Sudan grass. A grass was desired with the good qualities of Johnson grass but without the creeping rhizomes which have made this last grass a real pest. One of the botanists of the Bureau of Plant Industry predicted that such a grass would be found in the Anglo-Egyptian Sudan, and in 1909 Sudan grass, answering in every respect the special needs required, was introduced by the Department of Agriculture. Sudan grass is an annual belonging to the sorghum family. This grass makes a nutritious and palatable hay, greatly relished by both cattle and horses. The grass, since its introduction, has attained wide popularity as a summer pasture crop and has exceptional merit for supplemental pasture during the customary drought period of late July and August. The area planted with this grass is about 1,000,000 acres each year.

Among other grasses introduced by the Department which are now filling more or less important needs are crested wheatgrass, introduced from Siberia in 1898; centipede grass, from China in 1918; Napier grass from equatorial Africa in 1913; Rhodes grass, a drought-resistant species brought from South Africa in 1902; Natal grass, brought from South Africa in 1891: and woolly fingergrass, introduced from South Africa in 1928.

The introduction of these grasses and the studies made of them have served greatly to advance and maintain a successful agricul-

ture in sections of the country where it had been difficult to grow grass crops. All such introductions necessarily require careful testing for value. These scientific tests and studies are conducted at Department field stations and in cooperation with State experiment stations in all parts of the United States. Often very small quantities of seed are obtained, and to avoid losing all in field plantings, through risks of climatic conditions, some of the seed is germinated in the greenhouse and the seedlings well-rooted in pots before they are sent to the field. This method has proved successful. Along with this work, grass nurseries for testing introductions have been maintained at strategic points in the Middle West, the South, and the Southwest, and on the Pacific coast. The determination of the territorial limits of adaptation, as well as the cultural requirements and feed value, of these introduced grasses has been a matter of first importance and will require continued attention in the future, since new grasses are introduced each year.

The Problem of Breeding Grasses

In the field of breeding grasses, lack of knowledge of proper technique and inherent difficulties in handling the floral parts has limited the endeavor. One other reason may also be set forth—namely, the fact that so many new and promising grasses have been coming forward through introductions that the need for breeding work has not been felt so strongly with this group of crop plants as with some others. However, the time is at hand when it would seem that breeding work might greatly advance our field of knowledge of this important group. Such work has been inaugurated on a scale commensurate with its importance.

AGRICULTURAL ENGINEERING

Recent changes in economic conditions have shifted the emphasis of research in the utilization of irrigation water from attempts to obtain the maximum crop from a limited supply of water to efforts to lower the cost of crop production. Investigations in the Bureau of Agricultural Engineering indicated that labor costs and investment in distribution works usually can be reduced with increased efficiency in the application of the water.

The situation in the Northwest boxed-pear industry is illustrative. A few years ago there was a market at high prices for all pears produced in the Medford, Oreg., area. Even poor orchards on poor land were profitable. Normal production now exceeds the demand, and marketing agreements are in effect to withhold the less desirable sizes from the market. However, a large part of the crop is exported, and any great artificial price increase will cut off much of the foreign market. Research suggests that irrigation of the better orchards may be pushed beyond maximum yield per unit of water, well toward maximum yield per unit of land area. By concentrating water on the better land and forcing poorer land out of production, production costs may be reduced.

Because tractor fuel must be purchased whereas stock feed can be produced on farms, some reversion from mechanical power to animal power for farm work took place when farm incomes declined

after 1929. The change appears, however, to have been only temporary, despite acreage limitations under the crop-adjustment programs. In areas hard hit by the drought last year, dependence on home-grown feed is a disadvantage. Rental and benefit payments to farmers have provided some funds for the purchase of power equipment, and manufacturers of farm tractors are operating at capacity. Small general-purpose tractors are especially in demand.

The small general-purpose tractor, fairly suited in size and cost to the needs of a farm of moderate size, is one of the most important improvements made in farm machinery in the last few years. It was available in quantities in 1933 and met with ready acceptance. Previously the movement in farm-machinery design had been toward more powerful tractors and larger capacity tillage and harvesting equipment, the use of which involved a considerable investment.

Rubber Tires On Farm Machinery

Another development has been the use of rubber tires on agricultural machinery. These permit greater speeds between field and farmstead and between field and field. Rubber-tired tractors, for road speeds of 30 miles per hour or more, may soon be available. Farmers will be able to use them with inexpensive trailers, and will have less use for motor trucks. By absorbing shock and vibration, rubber tires prolong the life of the equipment on which they are used and under some soil conditions give better traction in field work than wheels with steel lugs.

The small combined harvester-thresher may replace many binders and threshers in the Corn Belt and the Middle and South Atlantic States. Apparently this machine harvests and threshes satisfactorily a greater variety of crops at less cost both for purchase and for operation than the machines it is replacing.

Three years of experimentation in Alabama with machinery used in growing cotton indicate a radical and profitable departure from customary tillage practices in some sections. Many of the more elaborate methods of seedbed preparation have been followed consistently by lower yields of seed cotton. Apparently these methods destroy desirable soil-structure conditions. This indication emphasizes the importance of the work planned for the Department's new farm-tillage machinery laboratory at Auburn, Ala., which has just been completed with Public Works Administration funds.

American lint cotton in world markets has been severely penalized on the basis of low spinning quality, presumably due to rough ginning. Under the authorization for cotton-ginning investigations enacted in 1930, laboratory experiments with commercial equipment have demonstrated the advantage of artificially drying sappy or damp seed cotton before ginning in bettering the grade of the lint and reducing the chokages and delays in ginning operations usually experienced with moist cotton. Drying increased the lint value of wet long-staple cotton about 8 percent, and that of wet short-staple cotton about 2 percent, on the basis of central market prices. Both the "Government" cotton-drying process and the vertical seed-cotton drier are inventions for which public patents have been granted to a Bureau engineer. This type of drier is rapidly becoming standard cotton-gin equipment, especially in the Mississippi Delta region. Fast ginning, char-

acterized by a tight seed roll, has been found to have a tendency to lower the preparation and grade of the lint, which has been especially evident with the longer staple cottons. A promising means of obtaining the advantages of the loose seed roll without sacrificing speed of ginning seems in view. Continuation of the cotton-ginning investigations is confidently expected to obtain improvement of ginning practices that, when generally adopted by ginners, will result in great improvement in the quality of the American cotton crop.

Machines for Sugar-Beet Work

The importation of transient labor into some areas for sugar-beet work involves social as well as economic problems. A mechanical means of cross-blocking has been devised by the Department's engineers which reduces the labor required and also reduces the cost for blocking and thinning the beets by more than one-third. A harvester developed in cooperation with machinery manufacturers reduces the labor requirement at the end of the growing season. With the needs of the crop more nearly within the resources of the producing areas and with growers less dependent on hired labor, the undesirable features of transient labor will largely disappear.

A farm-housing survey in 1934 focused attention on the run-down condition of many farmhouses and the general lack in rural districts of such conveniences as clothes closets, running water, plumbing, central heating systems, and electric labor-saving equipment. While the present need for repairs and the general deteriorated condition of farmhouses is, no doubt, due largely to the depression, the lack of conveniences cannot similarly be blamed on the hard years since 1920, for the same lack existed also during the relatively prosperous period from 1910 to 1920. In proof of this, the 1920 Census shows that only 10 percent of the farmhouses had water piped to them; therefore 90 percent had no plumbing. It is certain also that less than 10 percent of the farmhouses had adequate heating equipment or electric conveniences in 1920.

The long-standing low level of housing on farms is probably due in large part to the public attitude toward the farm home. The prevailing view has been that earnings and savings should be invested in land or other productive equipment, to enlarge the farm business. This neglect of the home and emphasis on production may have contributed to the piling up of surpluses and the collapse of farm prices. It doubtless has been partly responsible for the migration from country to city of many retired farmers and many young people desirous of a better living.

ECONOMIC RESEARCH AND SERVICE

The Bureau of Agricultural Economics was organized in 1922, when the first great post-war crash in the prices of farm products had focused public attention upon farm economics. It became a sort of central economic clearing house for agriculture and undertook comprehensive studies of the production, marketing, and distribution of farm products.

The Bureau's activities covered research, market news, and inspection, and the administration of certain laws such as the Grain Futures and Cotton Standards Acts. From 1920 onward, farmers had

to face distorted price relationships. The Bureau of Agricultural Economics accordingly developed methods of price analysis to show the trend of prices and of price relationships. It established price indexes currently and for pre-war years, to serve as a stable basis by which to compare later movements. These indexes became a basic measuring stick for farm-relief legislation. The parity-price objectives set up in the Agricultural Adjustment Act originated directly in the indexes which were established as a result of the Bureau's research in price analysis.

The Bureau also made numerous analytical studies of the prices of individual farm products, and these studies became useful as guides in production and marketing. Many interesting facts were established quantitatively for the first time. For example, a study of lamb prices considered the relation between the supplies of dressed lamb, the price of lamb at wholesale, the price of competing products such as beef and pork, the price level or the value of money, changes in the purchasing power of consumers as indicated by business activity, and the differences in demand throughout the season. From these data it became possible to forecast the price of lambs within a margin of accuracy that about equals the forecast of supply. Comprehensive facts were established on the movements of prices of the other principal farm products, such as hogs, beef cattle, potatoes, wheat, corn, cotton, apples, etc. Similar work was carried forward in the analysis and forecasting of the acreage, the yield, and the production of most of the important products.

Estimates of the size of the crops had been made for many years. Farmers had need, however, of advance information to guide planting and breeding. The Bureau developed a new type of crop report, which summarized the farmers' intentions to plant given crops. For several years now these intentions-to-plant reports have been issued well in advance of planting dates in most States, and have given farmers an opportunity to change their plans when there is danger of shifting too far in one direction.

The intentions reports on potatoes, plantings of which do not depend on weather conditions, have so modified farmers' plans that it has been necessary to extend the service on a regional basis. As the planting season progresses from south to north, potato growers in each belt of States get statistics on the acreage already planted to the south and on the acreage planned by growers in their own group of States. Potato growers are now able to avoid some of the heavy losses they formerly suffered through ignorance of prospective plantings.

The frequency, accuracy, and variety of the crop reports helped to make possible the successful development of the Agricultural Adjustment Administration production-control programs. In turn, these programs necessitated still more varied and frequent crop reports. The crop-estimating service last year issued a warning late in May that a national shortage of hay was unavoidable and that some of the principal grain crops were seriously threatened by drought. This warning caused the Agricultural Adjustment Administration to modify the crop-control programs while there was still time for an extensive planting of soybeans and other late crops. As a result, the shortage of feed and fodder in the fall of 1934 was less serious than it would otherwise have been.

Research in Marketing

The gross income of farmers can be increased in either of two ways: (1) By inducing consumers to spend more for agricultural products, and (2) by reducing charges for transportation, processing, and marketing. During the past 2 years the emphasis of the Agricultural Adjustment program has naturally been on the first of these. Unsalable surpluses have been reduced or eliminated in order to raise prices and to induce domestic consumers to spend more money for agricultural products. The incomes of farmers have been raised substantially by this process.

However, it is apparent that consumer expenditures for agricultural products cannot be raised indefinitely by any action of farmers, since it is definitely limited by the amount of income the consumer has to spend. Until consumer incomes rise from their present levels consumers are not likely to spend much more for food and other agricultural products than they did this year. Our production program, therefore, should not call for continued reductions, but only for a prevention of recurring surpluses.

There is still an important possibility of increasing the income of farmers and at the same time greatly benefiting consumers by more efficient transportation, processing, and marketing. A new Division of Marketing Research has been organized this year in the Bureau of Agricultural Economics, and one of its principal purposes will be to discover more efficient methods which will lower the high spread between prices received by farmers and prices paid by city consumers.

Among the first studies undertaken in the new Division are several statistical comparisons of prices at the farm with prices in city retail stores in order to get a good estimate of price spreads. Estimates have been published covering 10 important foods: Beef, pork, hens, eggs, milk, butter, cheese, potatoes, flour, and bread. A month's supply of these foods cost a typical workingman's family $19.06 in 1934. The farmer received $7.34 cents for the farm products used in making these foods, while the remaining $11.72 went to pay the various charges between the farmer and the consumer.

Of each dollar spent by the consumer for these 10 foods, the farmer got 38½ cents. Probably if all goods were included in the estimate, the farmer's share of the consumer's dollar would be somewhat less than 38½ cents, as no fruits or vegetables are included in this list of foods, and the farmer's share of the dollar spent by consumers for some fresh and canned fruits and vegetables is very low.

During the decade from 1920 to 1929 the farmer received about 50 cents of each dollar spent by consumers for these 10 foods. His share dropped after 1929 because charges for transportation, processing, and marketing were not reduced (and probably could not have been reduced) in proportion to the drop in food prices. The tendency for marketing charges to be relatively inflexible has been a very important factor in reducing the incomes of farmers.

Prospects of Getting Results

It is not a simple matter to reduce marketing costs, but if we realize the importance of these costs and undertake an adequate program of marketing research we should be able to make some

progress. Fraudulent practices and dishonest charges can be greatly reduced by good enforcement of proper legislation. Unnecessary duplication of services and facilities, both in the country and in the city, can be avoided, at least in part, by education, by cooperative marketing, and by marketing agreements. Transportation rates both by rail and by truck need continuous study to provide farmers good service at the lowest possible rates. Facilities in many of our largest terminal markets are very inefficient and add greatly to marketing costs, cause unnecessary spoilage, and reduce the potential consumption of foods.

Farmers and middlemen are constantly experimenting with new marketing methods, and these experiments must be watched carefully in order that real improvements may be adopted as quickly and as generally as possible. Among the most important recent developments are the increased amount of direct marketing of almost all farm products, the rapid growth of distribution by motor truck, the development of auction markets at country points, new methods of cooperative marketing, and the growth of large chain-store systems and other large distributors of farm products.

Most of these developments have good and bad features. Some of them doubtless offer possibilities for more efficient marketing. All of them, and many other marketing developments, should be carefully studied with a view to developing in this country the most efficient marketing system possible.

HOME ECONOMICS

For the general welfare, it is important that the products of the Nation's business, whether in agriculture, industry, science, or the arts, be fitted to the needs of the consumers. Ill-planned or unplanned production, disregarding or unaware of consumers' actual needs, makes for waste and maldistribution of supplies. But it is no less important that consumers make intelligent, economical choice and effective use of the products spread before them by the vast producing machinery of our times. Ignorant, haphazard, uncritical choice, and wasteful or harmful use of goods and essential services work to the detriment of consumer and producer alike, and thus of the Nation as a whole.

The ultimate consumers, however, live in family groups, and it is for the household unit that a vast proportion of producers' goods are purchased. The producer and the dealer are dependent not only upon the purchasing power of the family, but upon the ways of life in the household, its needs, desires, and standards. And considered in the large, the character, quantity, and uses of the goods the household buys are vital not only to the health and well-being of the family, but to the living standards of community and Nation.

The management of the Nation's households thus affects the whole national economy. Changes in household standards or technique create new demands upon industry, new markets for its goods. The producer and the technician have their stake in the economics of household management, just as the housekeeper has her stake in the economics of agriculture and industry whose goods and services she buys.

The Department of Agriculture, realizing the interdependence of farm producers and home consumers, studies consumption problems

from both points of view. One of its agencies for this purpose is the Bureau of Home Economics. The broad economic purpose of the Bureau's program is to raise national levels of living by encouraging more effective consumption. At the same time, by study of consumers' needs, it points the way to more effective production.

Carried out in detail, such a program must deal with all the everyday problems of the home and family. Practical home economics means economical management of the family income and intelligent buying of the commodities of household use. It means knowing foods and markets, food values and diet, quality in clothing materials, household goods, and fittings. The care of the house, the preparation of the food, and the housekeeping job as a whole require a hundred skills. Home economics is in fact the science of applying science to the household.

The Scientific Approach

As a science it must be studied. Even the "born housekeeper" cannot know by instinct all she must know to run her home efficiently. For the elemental task of feeding the family there is a world of new knowledge nowadays. Physiologists, nutritionists, and clinicians are showing the close relation between the kind of food we eat and our health. The Bureau of Home Economics studies food, food values, and nutrition, and applies the findings to the practical everyday task of meal planning with reference both to good diet and to costs. So also with clothing, house furnishings, and housing, the Bureau studies fabrics, methods of use, construction, and care, to determine the qualities in ultimate-consumer goods contributing the most to consumer satisfaction, and to establish standards to guide the consumer in buying. Finally, the Bureau's studies seek to show how goods and services available can be combined best to meet the needs of families of varying composition and different levels of income.

In the field of food uses, considerable advance has been made. Some of the Bureau's studies have been directed to show by diet patterns how families of various sizes may select their food to meet, at different cost levels, current food habits and at the same time the demands of good nutrition. These same diet plans tie in fundamentally with the land-utilization and food-production plans of the Department of Agriculture. The Department, while mainly concerned with production which will be most profitable to farmers, has also a responsibility for the protection of national health, and food production should be planned with the requirements of national health in mind.

Such food plans are necessarily drawn in broad, general lines. The detail must be filled in with many special studies, which, of course, take on a new significance when viewed as a part of the whole. The importance of small things in nutrition—the vitamins and trace mineral elements—makes much detailed research necessary and ties the human-nutrition studies in rather closely with the scientific studies of the various production bureaus.

Composition of food varies with the soil and other cultural conditions. Certain soils produce foods toxic to animals and also to humans. In other areas the soil conditions are such that foods grown there are deficient in some mineral element, as for example,

copper and iron essential for hemoglobin formation, with the result that a high percentage of anaemia is found in the children fed too exclusively on foods grown in these areas. Although problems such as these would probably yield to fertilizer treatment, food-composition studies help to show where such treatment is necessary, and by cooperative effort the condition can be corrected with considerable advantage to public health.

Clothing and Housing

While the relation of clothing to health is not so direct as that of food, the expenditures for clothing and household textiles come next to costs of food in many families, and the selection and care of these commodities are an important economic consideration in the family budget. The Bureau studies the composition of textile fabrics with a view to guiding the consumer in the choice and use which will contribute most in real satisfaction. Wise choice and care of clothing may add much to self-respect and happiness as well as to the physical comfort of the individual.

DAIRY INVESTIGATIONS

Improvement in the great mass of our milk-cow population will depend on the development of breeding herds from which the average dairyman can obtain herd sires that will consistently beget uniformly high-producing daughters. The Bureau of Dairy Industry is demonstrating the possibility of developing herds or strains of dairy cattle of such purity in their inheritance for high production that practically all the females born in the herd will be high producers and the young bulls can be counted on to transmit high levels of production. For example, 49 young Holstein-Friesian bulls bred in the experimental herd at Huntley, Mont., have sired a total of 579 daughters in farmers' herds near that station. These daughters averaged 11,227 pounds of milk and 404 pounds of butterfat, an average increase of 1,452 pounds of milk and 57 pounds of butterfat over the production of their dams. Many of the records were made on farms where little or no grain was fed. Only 5 of the 49 young bulls lowered average milk production, and only 3 lowered average butterfat production, and in each case by insignificant amounts.

During the year the Bureau began a study to determine in commercial breeding herds and in college and experiment station herds, what progress has been made toward fixing an inheritance for high levels of milk and butterfat production. When all these herds have been analyzed, dairy-cattle breeders will be in position to make more rapid progress in developing "pure-line production" herds by concentrating and extending the use of the superior germ plasm of outstanding strains and herds.

Roughage crops usually produce the nutrients necessary in dairy production at less cost than the grain crops. With grasses and perennial legumes the cost is often less than half as much as with the grain crops. Feeding experiments at various field stations show that good dairy cows will produce remarkably high yields of milk and butterfat when fed exclusively on good-quality hay and other roughage. On an average, these experimental cows have produced

from 65 to 75 percent as much butterfat when fed exclusively on good roughage as when fed the so-called "full grain" ration and roughage; when fed roughage and a half grain ration they have produced 90 percent as much as when fed a full grain ration. Since approximately three-fourths of a cow's potential production can be obtained with roughage nutrients that cost less than half as much as the grain nutrients, the wisdom of devoting the greatest possible acreage of the farm to grass and roughage crops is apparent.

Use of Dairy Byproducts

One of the most promising possibilities for increased returns lies in the development of a wider use of the byproducts of dairy processing plants. Nearly half the milk produced in the United States is used in the manufacture of butter and cheese and other dairy products. In the manufacture of butter, only the fat of the milk is used; in the manufacture of cheese only the fat and casein and a relatively small proportion of the soluble constituents are used. The remaining milk solids are left in the skim milk, buttermilk, and whey. Thus in producing the butterfat for the 1,650,000,000 pounds of creamery butter made last year, farmers produced something like 3,000,000 pounds of other milk solids that were not used in the butter. The whey from cheese manufacture contained an additional 300,000,000 pounds of milk solids not used in the cheese. Although nearly as much feed is required to produce the solids not fat as is required to produce the fat on which the farm value of the milk is based, the market price per pound for the solids not fat is only about one-fourth that of the fat. Furthermore, only a part of the potential output of solids not fat is marketed, even at this relatively low price. Rather than encourage higher butter and cheese prices, whereby consumption may be curtailed, substitutes used, and imports encouraged, the Department considers it much more desirable to obtain a fuller recognition of the value of the milk solids in byproducts, particularly their value as human food.

GRAIN FUTURES ADMINISTRATION

Two cases of outstanding importance, involving charges of price manipulation and making false reports to the Grain Futures Administration, were brought during the year before the Commission named in the Grain Futures Act. The Commission is composed of the Attorney General, the Secretary of Commerce, and the Secretary of Agriculture. In both cases the respondents were prominent exchange members.

One of the respondents caused at least eight commission houses in Chicago to keep false records and make false reports to the Government. He traded through 35 different accounts carried in the names of relatives and friends. Had the Commission in its proceedings joined as parties the commission houses involved, the resulting liquidation of open trades would have affected the market greatly and injured countless innocent persons.

Short sales of wheat by this one operator over a 2-year period amounted to more than 73,000,000 bushels. At one time he was short 7,525,000 bushels. In 1930 he was short 79 percent of the time; and in 1931 he was short 89 percent of the time. Yet in 1932 he caused

a series of articles to be published picturing himself as being always a speculative buyer, and complaining that the Grain Futures Act hampered his speculative activities.

In the other case, the Commission found the respondent guilty of having in 1931 cornered the July corn future at Chicago. The price was forced up 14 cents per bushel during the last 3 days of the delivery month. Only in isolated instances could producers take advantage of the temporary boost in prices. Other markets and other futures were not affected. In this case, too, the respondent used dummy accounts.

In each case the Commission found that the respondent had violated the Grain Futures Act, and issued an order denying him trading privileges on all contract markets for 2 years. Both cases have been appealed to the United States Circuit Court of Appeals in Chicago, and meanwhile the orders are in abeyance.

The principal point of the defense in both cases was a deficiency alleged to be in the Grain Futures Act, which says that if the Secretary of Agriculture has reason to believe "that any person is violating any of the provisions of this act, or is attempting to manipulate the market price of any grain" he may initiate proceedings. It was contended that the use of the word "is" limits action to cases in which a person is caught in the act of violating the law or of attempting to manipulate prices, and that no proceeding is authorized against a person who has completed the act of violation or manipulation.

To obviate this contention in the future the words "or has violated" are added to the language above quoted by the bill to amend the Grain Futures Act, H. R. 6772, of the last Congress, which passed the House of Representatives and was reported favorably by the Senate Committee on Agriculture and Forestry. It would also bring price manipulations and market cornering within the penal provisions of the act, and subject offenders to fine and imprisonment. The prospect of a jail sentence would discourage from attempting either to manipulate prices or engineer corners many who otherwise might risk suspension from trading privileges.

Proposed Amendments to the Law

Proposed amendments to the Grain Futures Act would authorize definite limitations on short selling and on purely speculative trading. They would make it unlawful for commission firms to cheat, defraud, or deceive customers, or to use the margin moneys of their customers for the benefit of others. They would outlaw cross trades, wash sales, and other devices for registering fictitious trades or fictitious prices.

Also, the amendments would guarantee that cooperative associations admitted to membership in the grain exchanges would have the benefit of a hearing before the Commission named in the Grain Futures Act before being suspended or expelled. Under present law, if cooperative associations are suspended or expelled without cause, they may appeal to the Commission; but the only remedy which the Commission can give is to revoke the contract-market designation of an exchange and stop future trading on it entirely. Meantime, during the litigation, which may take a year or more, the cooperative association is without membership privileges.

It seems desirable to preserve future trading, because a properly conducted futures market affords facilities for hedging by dealers against price changes. Continued opposition by the exchanges to more appropriate and more adequate control measures must lead ultimately, however, to the adoption of other methods of insuring against market risks. Unless the system can be conducted on the high plane of responsibility required of other institutions that similarly affect the public interest, the Government will be called upon to supply some form of price insurance that will merit public respect and public confidence.

ROAD CONSTRUCTION

Road construction in which the Department participated during the year resulted in the completion of improvements on 21,722 miles of roads and streets. Of this large mileage, 19,033 was improved with funds administered for the Federal Government solely by the Department. The remainder consisted of 99 miles of national-park roads, built for the National Park Service by the Bureau of Public Roads; 2,501 miles in loan-and-grant projects of the Public Works Administration, also supervised by the Bureau of Public Roads; and 89 miles in work-relief projects on which labor was supplied by the Federal Emergency Relief Administration, other costs were paid with Public Works funds, and supervision was furnished by the Bureau of Public Roads and several State highway departments.

By far, the larger part of the work on which the Department was the sole Federal agency consisted of construction carried out under various appropriations in cooperation with the highway departments of the various States, Hawaii, and the District of Columbia. Projects of this class completed during the year involved 17,344 miles of roads and streets—11,092 miles on the Federal-aid highway system outside of cities, 1,205 miles on extensions of the Federal-aid system into and through cities, and 5,047 miles classed as secondary or feeder roads. Also completed were improvements on 1,232 miles of forest highways and 456 miles of highways through other public lands built by the Bureau of Public Roads, and 8,962 miles of forest roads and 3,242 miles of trails built by the Forest Service.

At the close of the year the current program involved improvement of an additional 30,238 miles in all classes of projects, including 8,414 miles on the Federal-aid system outside of cities, 1,226 miles on city extensions of the Federal-aid system, 8,395 miles of secondary or feeder roads, 1,225 miles of forest highways, 45,047 miles of lesser forest roads and 103,048 miles of trails, 481 miles of public-lands highways, 725 miles of national-park highways, 1,134 miles in loan-and-grant projects, and 8,638 miles of work-relief roads, the last three supervised by the Bureau of Public Roads as agent for other Federal departments.

The Federal funds available for road construction and used in the work of the year were provided by a number of appropriations. The total expenditure from funds placed directly at the disposal of the Department was $290,300,699. Of this sum, the largest amount, $215,083,475, was drawn from the $400,000,000 earmarked for highways in the National Industrial Recovery Act; $44,791,372 was from the $200,000,000 fund authorized by the Hayden-Cartwright Act of

June 18, 1934, and lesser amounts were derived from other appropriations, as follows:

Emergency Relief and Construction Act of 1932	$2,135,663
Federal-aid highway appropriations	12,657,267
Appropriations for forest highways, roads, and trails	11,753,962
Appropriations for roads through public lands	3,878,960

These expenditures do not include $34,800,000 disbursed to State highway departments in advance payment for work authorized by the National Industrial Recovery Act and the Hayden-Cartwright Act, or expenditures by States for work completed on projects, probably exceeding $80,000,000, for which reimbursement had not been made by the Federal Government on June 30. Nor do the reported expenditures include any sums paid for work done on national-park highways under the engineering supervision of the Bureau of Public Roads, for loan-and-grant highway projects approved by the Public Works Administration, or for work-relief projects also supervised by the Bureau.

At the close of the year there was an unobligated balance of $36,717,772 in all highway funds appropriated directly to the Department, including $5,018,643 appropriated by the National Industrial Recovery Act, $28,241,383 authorized by the Hayden-Cartwright Act, and other funds for forest- and public-lands road construction amounting to $3,457,746.

To these balances there were added on July 1 additional funds authorized for the fiscal year 1936 in the amount of $137,500,000, consisting of $125,000,000 for Federal-aid highways, $10,000,000 for forest highways, roads, and trails, and $2,500,000 for roads in public lands. When to these are also added the $400,000,000 recently allotted for highway construction and the elimination of hazards at railroad grade crossings, the total funds available at the beginning of the fiscal year 1936 is raised to $574,217,772. Of this amount, all but the balance of $36,717,772, above mentioned, has become available since June 1, 1935.

Provision of Employment

In the highway work of the past 2 years the provision of employment has been the predominant motive, and various conditions have been imposed to increase the amount of individual employment furnished by the expenditure of the Federal funds. Among these have been the general limitation of hours of labor to 30 a week, the substitution of manual labor for machine work wherever practicable and consistent with sound economy and public advantage, the requirement that projects be developed in relation to employment need and in as many places as practicable, and the stipulation that the labor directly employed on the road work be obtained from local agencies of the United States Employment Service.

The effect of this effort is shown in the record of employment furnished, which slightly exceeded in 1935 the previous high record of the fiscal year 1934. The total employment furnished during the year on work supervised by the Department was 2,233,855 man-months. This is equivalent to an average full-time employment of 186,155 men each month, but the number of individuals actually employed, on account of part-time employment and other reasons, averaged approximately 302,350 persons per month; and to this

should be added the indirect employment supplied in the production and transportation of materials and equipment. It is estimated that such indirect employment required by the work done has averaged approximately 1.4 times the direct employment, and on this basis the indirect employment afforded during the fiscal year 1935 is estimated at 3,127,400 man-months, which, added to the direct employment, results in a total of approximately 5,361,000 man-months for the year, equivalent to a continuous average employment through the full year of 446,700 men.

Until the passage of the National Industrial Recovery Act Federal funds for road construction were expendable only on the important interstate and intercounty roads included in the Federal-aid highway system and on roads in the national forests, parks, and other Federal areas. Expenditure on city streets and local rural roads not included in the Federal-aid system was specifically prohibited by law.

Secondary or Feeder Roads

With the primary purpose of serving the employment need, the National Industrial Recovery Act provided that a portion of the money earmarked in it for highway construction be expended on secondary or feeder roads and on extensions of the Federal-aid system into and through municipalities.

By rules and regulations prescribed by the Department the term "secondary" or "feeder" roads was defined as applying to any road not included in the Federal-aid system. Upon such roads it was required that there should be spent not more than 25 percent of the money apportioned to each State. Not less than 25 percent was required to be expended on connections through cities.

In the expenditure of the funds authorized by the Hayden-Cartwright Act increasing emphasis was placed upon secondary-road improvement by requiring that not less than 25 percent of the new apportionments should be spent on roads of that class. And, whereas a large part of the mileage improved under the earlier act had been in roads of sufficient importance to be included in the several State systems, a special effort was made to provide with the new money for the improvement of the more important local roads.

This tendency to give increasing attention to what may be called farm-service roads, as distinguished from main arteries, has been carried still further in the requirements laid down for the expenditure of the $200,000,000 recently allotted for highway construction from the appropriation made by the Emergency Relief Appropriation Act of 1935. For purposes of this expenditure secondary or feeder roads are defined as roads not included in either the Federal-aid or State highway systems, and it is required that not less than 25 percent of the allotment shall be spent for the improvement of such roads.

INTERNATIONAL COOPERATION IN WEATHER STUDIES

In the work of the Weather Bureau international cooperation is a vital factor. For more than 60 years the directors of national meteorological services have been meeting regularly to exchange ideas and

information and to secure harmony and standardization for effective cooperation. Meteorology is essentially world-wide in its scope. No country, whatever its geographic area, is large enough to be independent of other countries in providing its people with an adequate weather service.

The International Meteorological Organization is wholly voluntary, and not governed by treaties or conventions. Its recommendations are expressed in the form of resolutions, adherence to which is only a moral obligation. It meets once every 6 years. This year (1935) the sexennial meeting was held at Warsaw, Poland. Subcommissions meet as frequently as circumstances warrant, usually every 2 or 3 years. Most of them met this year just prior to the major meeting. Representatives from the United States Weather Bureau were the Chief of the Weather Bureau and the Chief of the Division of Climate and Crop Weather.

Exchange of observations is the most important feature of this international cooperation. It is done principally by radio, but occasionally by cable or telephone. Internationally standardized definitions, codes, etc., facilitate application of the data. The United States cooperates most completely with Canada. There is no meteorological boundary line between the two countries. Most Canadian reports are received at United States forecast centers as promptly as at Toronto, and observations at United States stations are as promptly sent to Toronto. Exchange arrangements also exist with Mexico, with the Philippines, with the Far East, and with meteorological organizations in the West Indies.

Twice each day, at 11 a. m. and 11 p. m. eastern standard time, bulletins are transmitted by radio directly from the Weather Bureau in Washington through the Navy radio stations at Arlington and Annapolis for the benefit of European meteorological services. These bulletins contain about 100 reports representative of weather conditions in North America and reports from ships in the western Atlantic. Correspondingly, twice daily, about 5 a. m. and 5 p. m. eastern standard time, bulletins containing about 100 European land-station observations and reports from ships in the eastern Atlantic are broadcast from the powerful Rugby station in England for the meteorological services in North America.

HENRY A. WALLACE,
Secretary of Agriculture.

Better Plants and Animals

A Survey of Superior Germ Plasm

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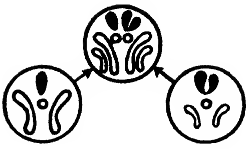
Better Plants and Animals



Foreword and Summary—The Survey of Superior Germ Plasm

SINCE life began, nature has been "breeding" plants and animals. She crossed them. She inbred them. She subjected them to mysterious forces powerful enough to bring about changes in the germ stuff that determines their characteristics. She put them through hardships that only the fit could survive. Out of these processes, carried on over millions of years, myriads of forms of living things developed.

For a long time after man came on the scene, he took what nature gave him. But being observant and determined, he eventually began to gather seeds from the fields and plant them for his own use, and to capture young animals and tame them. This was more handy than hunting and it gave him a more certain food supply. As he gained experience, he became dissatisfied with what he got from nature and began making improvements. He picked out the plants that seemed to yield the most and to be the more palatable and increased them, gradually discarding the others. He shrewdly selected the best animals for mating whenever he could. It was a slow, crude business, but there was plenty of time. Long before the dawn of history, these generations of picking and choosing resulted in most of the major types of agricultural plants and domestic animals we have today.

During this time the men who knew most about the processes of nature, or thought they did, were the magicians. Eventually the scientists appeared. They were the natural heirs, the seventh sons of the seventh sons, of the magicians, and they put the latter out of business because their ideas turned out to be more practical and effective. These scientists were natural-born meddlers; nothing was safe from their curiosity; they were driven by an experimental itch that would not let them leave anything alone. Some of the biologists among them saw possibilities for further improvement in plants and animals, and slowly and painstakingly they worked out more exact methods to bring it about.

As time is measured in the age of the earth or of man, the scientists who deal with heredity came on the scene only a few minutes ago, but already they have managed to do a great deal. In the case of plants especially, they have developed out of the old stock a large number of new forms with better quality, more productiveness, and greater resistance to disease and adversity. But they would be the

first to say that they have hardly scratched the surface, and looking into the future, they can see far richer possibilities as their science pushes forward with its exploration and experimenting.

For a long time, the young child creeps on all fours. It is an awkward, slow way to get around, but it is adequate for his needs. Later, in adult life, he would be enormously handicapped if he had no better method. Nature takes care of this; when the right time comes, the youngster has an irresistible impulse to walk, and walk he does.

THE science of the quality of life as it passes from generation to generation is in many respects the greatest and youngest of all the sciences. While the art of plant and animal breeding is an old one, the science of plant and animal genetics dates only to 1900. So far as known this Yearbook is the first comprehensive effort to survey superior germ plasm in the leading plants and animals. The Yearbook shows how much we know and also how much more we should know but do not as yet. True, the science of genetics is still young and growing. I trust that the day will come when humanity will take as great an interest in the creation of superior forms of life as it has taken in past years in the perfection of superior forms of machinery. In the long run superior life forms may prove to have a greater profit for mankind than machinery.

HENRY A. WALLACE.

So man got along very well with the old methods of agriculture throughout the long period of the world's youth. He needed nothing better. Under the changed conditions of the modern world, they would not suffice.

Modern science may be thought of as the parallel of walking. It enables agriculture to stride instead of having to creep. Even at that, it has to keep striding fast. Diseases that were not serious before, devastate modern close-packed plant communities as the Black Plague devastated crowded cities, and new varieties of plants have to be bred to resist each one. But then the disease organism may become adapted to the new plant, and it is necessary to develop still another

one. In the case of animals, scientists do not yet agree on the extent of hereditary disease resistance; but the same necessity exists as with plants, and there is increasing pressure to find out what are the limits of inheritance in this direction. In addition, the pressure of competition, new technological developments, and changes in ways of living make it imperative to keep on the job increasing efficiency and improving quality.

There is scarcely time to congratulate ourselves on the achievement of today because we have to hustle to produce something better for tomorrow. The task of the breeder and the geneticist has become never-ending.

The Discovery That Inheritance Follows Definite Laws

LIKE all great scientific developments, the modern science of heredity has a complicated background, and it was built up from the work of many men. By sheer reasoning, the Greek philosopher Aristotle worked out a theory of heredity not without its elements of truth. Camerarius, late in the seventeenth century, discovered that plants have sex and may therefore be cross-bred like animals. Darwin's theory of evolution was enormously stimulating to the earlier breeders, and their work in turn stimulated the thinking of Darwin. Weissman worked out in a clean-cut form the idea of a germ plasm passed on from generation to generation, transmitting inheritance. De Vries, the Dutch botanist, on the other hand, emphasized the sudden mutations that, appearing in the primroses he studied so carefully, changed inherited characteristics in a single generation. There were many others, including a host of practical plant and animal breeders—for example, the famous livestock men of the eighteenth century, Bakewell, the Colling Brothers, Bates, and Cruickshank—who, though they did not have the benefit of modern scientific discoveries, were eager experimenters and skillful artists in manipulating living things to get desired results.

The man who had the most influence in making the science what it is today is generally conceded to be Gregor Johann Mendel, the studious-minded monk who crossed garden peas in his monastery garden in Brünn, Austria, now Brno, Czechoslovakia. Mendel did a simple but revolutionary thing that apparently had not occurred to previous workers who had been trying to solve the secrets of inheritance. He carefully sorted the progeny of his parent plants according to their characters and counted the number that had inherited each character. By doing this, he discovered that when the things he was studying were handed on by the parents, they were distributed among the offspring in definite mathematical ratios, and in no case was there a significant variation from these ratios. For the first time, Mendel established definite laws of inheritance.

No attempt will be made here to describe Mendel's work, which is discussed in every elementary textbook on heredity, since it would be confusing to take the historical approach and describe changes in

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viewpoint and additions to knowledge from Mendel's day to our own. Concerning the precise influence of his work on modern scientific thought, as well as on practical breeding, there are differences of opinion. There can be no doubt, however, that much that had been sheer mystery in breeding operations became understandable as a result of his discoveries.

No one appreciated these discoveries until long after Mendel's death in 1884. Originally published in an obscure Austrian journal in 1866, they passed unnoticed for a third of a century. In 1900, three European botanists, Correns, De Vries, and Von Tschermak, also working on inheritance, independently came across Mendel's paper and had it republished. It not only corroborated the findings of other workers, like Spillman in the United States, working with plants, and Bateson in England, working with animals, but stimulated research and experimentation on so wide a scale that it finally included practically every country in the world.

Though it will be evident from some of the articles in this book that much worth-while work in the breeding of plants and animals was done long before 1900, this may be conveniently considered a turning point in the history of the science, and modern methods may be thought of as taking shape mostly after that date. In the brief intervening years, a vast amount of intensive work has been done, including the extensive researches of Thomas Hunt Morgan and his associates with the tiny pomace fly,[1] which lives so brief a time and reproduces so fast that work which would take years with other organisms can be telescoped into days. The science has become much more complex. Bright hopes of the speedy solution of some problems have been dashed. New problems have arisen. But there has been steady progress.

Genetics Becomes a Major Branch of the Science of Life

LOOKING back over this third of a century, four things stand out strikingly.

(1) Scientific breeding with both plants and animals has become a powerful and an indispensable tool for making agriculture more efficient and more flexible in meeting new demands and supplying the needs of men for food and raw materials. It has become a major branch of the science of life, taking its place beside modern chemistry and medicine as a means of conquering some of the chief difficulties and dangers that beset man, and giving him greater abundance.

But it has hardly begun to do what it should do in this direction. The average hen in the flocks of the United States produces 80 eggs a year. There are flocks of well-bred birds that produce over 200 eggs per bird per year. Average butterfat production is 165 pounds per

[1] Commonly called fruit fly or vinegar fly. "The correct name for *Drosophila melanogaster*, as approved by the Association of Economic Entomologists and officially used by this Bureau, is pomace fly." Lee A Strong, Chief, Bureau of Entomology and Plant Quarantine.

cow per year; the herds surveyed for this Yearbook average 450 pounds per cow per year. But of 4,000 dairy sires, representing what are considered to be the best herds in the country, surveyed for the Yearbook, only 300, or less than 10 percent, are listed as excellent from the standpoint of transmitting high production. Obviously the production of both eggs and dairy products in the United States could be greatly increased with no more hens or cows than farmers now have to feed and care for. In other words, costs of production could be greatly reduced by a wider application of scientific breeding. The basic significance of this is that neither egg consumption nor milk consumption is what it should be, especially in the lower income groups who make up so large a percentage of the population, because not enough people can afford enough eggs or enough milk for the best nutrition. Fundamental economic considerations, including the distribution of income, are involved here, but in any case scientific breeding should be a dynamic factor in producing the necessities of life at less cost, and putting them within the reach of more people.

(2) There is a close interdependence between practical breeding work and the theoretical science of genetics. The practical breeder can accomplish a great deal by dint of long experience, close observation, and a genuine feeling for his material; but the knowledge of how inheritance works, built up by theoretical research in genetics, enables him to go farther and faster, with fewer mistakes. How advances in theoretical knowledge affect practical methods is brought out in many of the following articles, and particularly in the discussion of modern corn breeding. There are many practical breeding problems whose solution definitely waits on the results of further genetic research.

(3) Like every other science, the modern science of heredity is international, not only in its theoretical findings but in its practical applications in agriculture. Some of the most valuable of our present-day varieties of plants in the United States, for example, trace their parentage back to far and obscure places. Scientists search the earth for breeding material that will be useful in improving the products grown in their own country. They exchange this material, and the results of their own work, freely between one country and another. What is the net effect of all this? A great improvement, of course, in productive efficiency in our own country—but equally, a great improvement in other countries. From its rivals, a nation may get the wheat germ plasm or the cotton germ plasm that enables it to supply its own needs or overwhelm those rivals in international trade. Exclusive monopolies, or even moderate advantages, tend to be broken down and leveled off at a rate that grows faster with every forward step of science. Will nations have the wisdom to deal with this situation, or will it lead to more bitter rivalries and more deadly conflicts, as the beneficent science of chemistry has enormously increased the deadliness of war? In his use of modern science, man has proved again and again that he is a bright child playing with fire.

(4) The field of breeding and genetics has become so large, it is so dependent on progress in basic research, and it requires such continuous effort on projects running over many years or even more than one generation, that it obviously becomes a function of governmental institutions capable of devoting the necessary money and

time to the work and doing it with a sufficiently disinterested attitude. This is especially true because the results are for the benefit of all people rather than any one group. In the future, the well-being of a nation will depend more and more on the vigor and adequacy with which it carries on this task of improving the forms of life on which it depends to feed, clothe, and house its people, and also on the vigor and adequacy with which it makes the improvements available to all its citizens.

The Cooperative Survey of Plant and Animal Improvement

BOTH in its practical and its theoretical aspects, the new science of genetics has so far been concerned primarily with agriculture; and because of the great importance and the varied nature of agricultural production in this country, workers in the United States Department of Agriculture and the State agricultural experiment stations have taken a leading part. So much has been done, and the situation is getting so complex, that the time seems ripe for surveying the field and taking stock of the harvest. With this thought in mind, one of the first things done by the present Secretary of Agriculture, who has himself been a plant breeder for some 30 years, was to appoint, early in 1933, the genetics committee whose members are listed at the beginning of this section of the Yearbook.

The task suggested for this committee by the Secretary was to undertake a survey, in cooperation with the agricultural experiment stations in all the States, of superior germ plasm in plants and animals. An organism with superior germ plasm may be defined as one that has hereditary factors for characteristics of genuine value and is therefore useful for breeding improved forms. Out of such a survey, the committee hoped to develop not only a comprehensive picture of what has been done and is being done in this field, with some forecasting of future possibilities, but also a detailed list of the superior varieties and strains of plants and the superior livestock that have been produced by breeders, with concise statements of their superior character, their ancestry, and the methods used in developing them. Such a list should be valuable as a directory of the plant and animal germ plasm available for selecting or combining to produce the superior crop plants and animals of tomorrow. It was decided also to extend the survey to foreign countries, since breeders draw their material from all parts of the world.

Survey forms designed to bring out the required data were drawn up first by the Bureau of Dairy Industry. These were modified for the other classes of livestock and served as suggestions for dealing with the crop plants. Thousands of forms were sent out, and the agricultural experiment stations responded with enthusiasm in spite of the mass of work involved over and above their regular duties. In some cases, notably dairy cattle, States made appropriations to cooperate in the work so that the surveys might be as complete as possible.

In spite of drawbacks and shortcomings, the effort produced notable results. In the case of the crop plants, a wealth of material poured in dealing with breeding work in the past and present, much of which is not available elsewhere and could not have been obtained by any other method. In general, the material from foreign countries was not as complete as had been hoped, but much of it was illuminating. In the case of livestock, only the dairy industry produced an actual listing of superior breeding material for analysis. Cataloging superior germ plasm in poultry proved to be impracticable chiefly because of the immense numbers involved and the methods used by most breeders. With beef and dual-purpose cattle, sheep, swine, and horses, the location of superior germ plasm was beset with other difficulties, notably the lack of standards by which to judge breeding worth from the standpoint of economically important characters and the emphasis placed on registration, pedigree, and accepted breed characteristics. In the case of these last five classes of livestock, however, the effort to make such a survey was valuable as a means of appraising the present situation and indicating the need for a new experimental approach. This will be brought out in the livestock articles that follow.

How the Present Book Developed from the Germ Plasm Survey

IT WAS decided that the most appropriate place to present this material would be the Yearbook of Agriculture, since nothing is of more vital concern to farmers than what is being done to improve plants and animals. The present Yearbook, therefore, is largely devoted to a series of articles that grew out of the survey of germ plasm. The results of the survey are given, together with a historical summary of what has been done in the past, a discussion of present work and future possibilities, some accounts of the methods used in modern breeding, and in most cases a brief discussion of theoretical research dealing with inheritance in the particular plant or animal. Only 19 major crops and types of livestock could be dealt with in the present volume, but the series will be continued in the 1937 Yearbook with articles on vegetable, fruit, and forage plants, flowers, forest and nut trees, honeybees, and some of the animals of less economic importance.

A fundamental difficulty had to be faced at the outset. The practical breeding of plants and animals has its technical aspects, and the science of genetics has become highly technical. A great deal of technical material, of value to students and workers, resulted from the survey. At the same time, the Yearbook reaches a wide audience, most of whom have had no scientific training in this field. The effort, therefore, has been to present the bulk of the material with sufficient simplicity so that it would not be more difficult to grasp than many things with which the intelligent farmer or student of agriculture has to deal in meeting every-day problems connected with the feeding and management of livestock, the cultivation of plants, soil practices, the use of fertilizers, and the care and operation of farm machinery. A

number of words unfamiliar to the general reader must necessarily be used. These are defined in the Glossary of Genetic Terms. A preliminary article describing broadly what goes on within the living cell tells about the fundamental life processes that underlie all of the breeder's work in improving plants and animals or adapting them to special uses. Illustrations, including pictures of many famous workers in this field of biology, are included wherever they would be of educational value. The most technical material, that listing varieties and promising new strains developed, and dealing with theoretical genetic research, is in each case at the end of the article, and the general reader may skip this if he wishes. Citations, or references to technical literature, are given in many cases, as in all scientific writing. Valuable data developed by the survey of germ plasm and research activities, but too detailed to be included in the text, are placed in an appendix to the article.

It is hoped that the book will stimulate many readers to study the subject of genetics further, and perhaps to carry on experiments of their own. Genetics is not less vital to the welfare of the human race than the science of nutrition, though probably the public in general knows a good deal less about it, since genes have received less publicity than vitamins. No field is more fascinating, and as far as practical breeding is concerned, those who work carefully can achieve interesting and worth-while results even without scientific training. Again and again it is shown in the following articles that farmers and others who perhaps never saw the inside of a laboratory have developed valuable plants and animals that have been widely used.

Some Notes on the Technique of Plant and Animal Breeding

WHETHER he is a professional or an amateur, the enthusiastic breeder of plants or animals is likely to have certain peculiarities, and there are certain requirements for success.

He must, above all, have a genuine love of his material and become so thoroughly identified with it that he knows its minute characteristics and can readily distinguish small differences in appearance, quality, and behavior that would be unnoticed by the casual observer. If he is working with wheat, for example, he must be able to go over a nursery containing many thousands of superior plants and select those that have traits for which he is searching; he may find only a single strain different from the rest, like a nugget of gold in a waste of rocks. Again, he must be able to classify many plants of each progeny in accordance with their characters, and do it rapidly and surely. This requires not only a trained eye but also something that almost becomes instinctive, like the feeling of an artist for his raw material, based on painfully acquired knowledge that eventually passes into the subconscious. This kind of observation and judgment, of course, is supplemented by scientific tests and precise measurements, but the feeling for the material must come first.

Again, the breeder who works with plants must be able to carry on many delicate manipulations with rapidity and precision. Some of his work is of the order of that done by a jeweler making filigrees with fine wires, or peering into a watch and putting together little wheels and springs under a magnifying glass. This demands not only a nice touch but a kind of patience that not everybody possesses.

The animal breeder, for the most part, does not have to do this kind of work. Nevertheless he, too, must have a genuine love for his material and the ability to select from thousands of available animals the ones whose germ plasm will produce the traits desired. He would contend that his work requires an even more accurately focused eye and a more highly developed artistic instinct than the work of the plant breeder, who can afford to make more mistakes and do more experimenting without financial chaos. Patience is a prime requisite with him also, since, like the plant breeder, he undertakes projects that may not be completed for many years, and many of which will turn out wrong and have to be abandoned or started all over again. But in addition, the animal breeder needs to have boldness mixed with his patience. When a plant-breeding experiment goes bad, no great loss is involved. Animal experimentation is a costlier business. Moreover, while the perpetuation of a strain of self-fertilized plants is a comparatively simple matter, with animals each generation opens up the possibility of recombinations of characters and the attendant loss of much ground previously gained. Yet when the animal breeder sees possibilities that look promising, he must take the risk. The timid soul has no place in this work.

It is sometimes said that the breeder assumes the characteristics of the material with which he works. More likely, it takes a certain kind of man to be strongly attracted to a certain kind of material. In general, the plant breeder must have a genuine liking for close, detailed work, with many thousands of small units, that might drive an animal breeder into nervous prostration. At the same time, it might be said with some justice that if the plant breeder had to limit the number of individuals he could raise to the levels with which the animal breeder must be content, the plant breeder would probably develop a case of numerical hysteria.

With two exceptions, animal breeding does not involve any unusual physiological technique. The exceptions are fairly recent developments—artificial insemination, and the use of hormones. In artificial insemination, the seminal fluid is collected and used to fertilize females by injecting it into the uterus. It is thus possible to multiply the number of fertilizations from a single sire; to utilize the inheritance in the germ plasm of a valuable male for combining with that of females at a considerable distance, provided the spermatazoa are suitably maintained and transported; and to cross organisms that ordinarily could not be mated. (Efforts are being made, for example, to cross the turkey and the chicken by artificial insemination.) Hormones are now used both as a positive test for pregnancy in animals well in advance of the time when it would normally be evident, and to induce or increase fertility when it is otherwise difficult to obtain.

The animal breeder is concerned with the physiology of several processes: The ripening or maturation of the generative cells—spermatozoa and ova; ovulation or the extrusion of ova from the ovary; the

oestrum or heat period; the union of egg and sperm cells, or the fertilization of the egg that follows mating; gestation, the period of pregnancy; parturition, or birth; and lactation, or the secretion of milk to feed the young. There is, of course, considerable variation in these phenomena among different animals, and the breeder must have an accurate knowledge of them, especially since abnormalities and diseases have a large effect on fertilization, gestation, and parturition. He is also vitally concerned with the genetic principles involved in systems of mating, and with methods of measuring performance.

There is so great a difference between fertilization in plants and in animals, in spite of their basic similarity, that the plant breeder has had to develop a special technique with three objectives—hastening natural processes, accomplishing what is not ordinarily done under natural conditions, and preventing what would ordinarily occur.

In the case of plants that have both male and female parts in the same flower, for example, it is necessary, in making crosses, to remove the male or pollen-bearing parts of all flowers chosen to be female parents. If this emasculation were not carefully done before the pollen matured, the plant might be fertilized by some of its own pollen, even in cases where this rarely occurs under natural conditions. The breeder therefore takes a small pair of forceps—different kinds of forceps have been designed for different plants—and reaches down into the flower and removes the anthers or pollen-bearing organs. Where the flowers are very small, as in the case of grasses, this is a delicate and tedious operation; with some grasses it is hardly possible, and emasculation is accomplished by washing the pollen from the anthers with a stream of water from a syringe. A skillful operator may manage to emasculate a hundred flowers in an hour's time, but he must do the work carefully so as to damage the flowers as little as possible, and it is not the kind of job that can be kept up all day.

The stigma of the emasculated female flower is allowed to develop for several days and is then dusted with pollen from the anthers selected as the male parent. Sometimes this is done with a small camel's-hair brush, sometimes with the fingernail, sometimes with a special pollen gun, sometimes by direct application of pollen-bearing anthers. If the pollen to be used is not quite ripe, it is sometimes ripened by being left in the sun on a watch glass. For careful genetic work, it is necessary first to cover the emasculated flower and later the fertilized flower or flower head with a glassine or paper bag to prevent any possibility of contamination with insect-carried or wind-borne pollen from other plants; fields of plants with bagged heads or flowers are a familiar sight in breeding work. It may be advisable also to stake the selected plant to prevent damage. The next step is to mark it with a tag carrying a number or other information about the cross. Complete information may be kept in a notebook.

The keeping of complete, accurate, and readily usable records is a vital part of the whole process, particularly in genetic analyses, and success or failure may depend on how well this is done. In some of the animal-breeding articles, it is brought out that lack of adequate or significant records greatly limits or may nullify the usefulness of breeding trials. In plant breeding, where many crosses are made and hundreds of selections are sometimes made from a single cross, all promising material may be saved whether it is immediately used

or not, perhaps to be used again later. Marquis wheat, for example, was developed from a selection of a cross not grown for many years but resurrected in the course of systematic trials of old material. Unless there are accurate records in such cases, it may be necessary to go over much of the ground already covered in tedious experiments.

The technique of fertilization varies with different operations and with different plants. Some of these variations are described later, for example, in the articles on corn, tobacco, and sugarcane. The plant articles also tell how selection is carried out for various characters, and how crosses are made to get specific characters into a plant that lacks them. Several of the articles—the one on barley, for example—tell about the long careful series of tests that must follow the production of any new variety or strain.

During the past quarter of a century, a great deal has been done to improve these methods of testing. An outstanding development has been the use of artificial inoculation to test for susceptibility to disease. The disease problem has become increasingly important, and plants are now bred to resist all the four types of disease—physiological, virus, bacterial, and fungus— as well as such unfavorable environmental conditions as excessive heat, cold, and drought. It is not too much to say that this is now the most important single task facing the plant breeder, and much remains to be done—there are 100,000 species of fungi alone, and they produce hundreds of diseases in plants. An effective part of the strategy against these swarming hosts of enemies is the use of artificial inoculation where it is practicable, since it both speeds up the work and makes it more certain.

The importance of large and varied collections of seed from all over the world is also brought out in several of the plant articles. These seed collections are to the plant breeder what the various kinds of clay are to the potter. The packets of seed are kept in cabinets in dry rooms and protected against insect damage. Before there is any danger that a given lot will have lost its vitality, it is planted in an isolated plot and new seed is harvested to take the place of the old. In this way it is possible to maintain source material over any length of time. If present collections were kept up, for example, our descendants hundreds of years hence would be able to reproduce the plants grown today.

Whether he is working with plants or animals, mathematics plays a large part in the task of the scientific breeder. Genes are units whose behavior is determined by what goes on within the individual cell in the processes of division and multiplication involved in handing life on from one generation to the next. The function of genetics, from the practical standpoint, is to enable the breeder to predict what will happen to a given gene or group of genes under a given set of conditions. When he knows this, he can arrange the conditions so that the result he wants will be brought about through the operation of natural laws. Insofar as he cannot predict perfectly, the failure is due to gaps in present knowledge at one point or another. The mathematical laws of chance are involved in the distribution of genes among offspring, and the whole process of calculating the possibilities involves much figuring. As in physics and chemistry, many useful shortcuts have been devised, and anyone who goes into the work seriously or on a large scale should become familiar with them.

A Bird's-Eye View of the Work in Plant and Animal Breeding

HOW much agriculture gains, in dollars and cents, from the work of plant and animal breeders it would be impossible to estimate. Two generalizations may be made, however: (1) In the realm of living things, with which agriculture deals, the work of the breeder is comparable to the work of the inventor in the realm of inanimate things, with which industry deals; and it pays in much the same way that invention pays when it continually replaces the old with the new or makes possible what was not possible before. (2) This work is becoming one of the major weapons in the battle that must be ceaselessly carried on against destructive forces, especially diseases. Even if breeding and genetic research had no other function, this one would be justification enough for the effort.

There can be no doubt that the investment made for experiment and research in the field of breeding and genetics pays many times over.

For the convenience of the reader, all the articles in the Yearbook that deal with specific crops and classes of livestock will be very briefly summarized below from material furnished by the authors. A few of the more important aspects of the present situation stand out in such a summary.

(1) There is a greater and greater stress on hybridization, particularly with plants, as the chief tool of the breeder. Formerly the stress was chiefly on selecting particularly good types, getting them to breed true, and using them to replace the old ones. Now the breeder tends rather to formulate an ideal in his mind and actually create something that meets it as nearly as possible by combining the genes from two or more organisms.

(2) He is no longer satisfied to create an organism with a single desirable trait, such as resistance to a certain disease. His ambition now is to get a great many desirable traits into one organism—for example, resistance to a whole group of diseases at once.

(3) In this connection, he has a new confidence—at least in the field of plant breeding—about being able to breed organisms that are inherently resistant to, or even immune from the major diseases. He has had enough success to make him believe that the possibilities here are still greater than present achievements.

(4) Certain new techniques for practical work are developing directly out of theoretical research, and these seem to hold much promise for the future. Perhaps the most advanced of these is the technique now used in producing hybrid corn. It has achieved striking success, but corn breeders do not hesitate to say that new advances in theoretical knowledge are likely to bring results that greatly exceed those so far attained.

(5) Although the breeder has by no means exhausted the possibilities of hybridizing closely related organisms, he is beginning to reach farther afield and experiment with wider crosses. He is inclined to be cautious about expressing himself regarding the possibilities here, knowing that failure is at least as likely as success; but down underneath, he has a vision of creating organisms different

from any now in existence, and perhaps with some remarkably valuable characters.

(6) Whether any very significant practical results can be achieved by bringing about direct changes in chromosomes through the use of X-rays, heat, and other forces remains to be seen. At any rate, this field of experiment is throwing new light on the underlying mechanism of inheritance.

(7) The livestock breeder is not nearly so far advanced as the plant breeder in applying genetics to his problems. As B. L. Warwick puts it in the February 1936 issue of The Journal of Heredity:

> The application of genetics to animal breeding up to the present time has been almost infinitesimal * * *. Most of the excellent breeds of fairly uniform animals are not the result of application of genetic knowledge, but of long continued empirical selection for the desired types.

There are many reasons for this backwardness, but scientists in this field are beginning to appraise the situation more critically, and to be more anxious to make a thorough exploration of the possibilities. In other fields, scientists dealing with animals have made notable contributions. A large amount of the new knowledge of human nutrition, for example, came from experimental work with animals, including farm livestock.

WHEAT

Two thousand years ago wheat had already been cultivated for so long that it was an ancient domesticated plant, and its characters had become fixed. Today it is so important in the economy of the world that it is grown in 50 different countries and on 300 million acres annually. In recent times there has been much successful effort to improve the wheat plant in the United States and in all the important wheat-growing countries.

In the early period in the United States the work of producing improved wheats was done by private individuals or agencies, including farmers. Following the establishment of the United States Department of Agriculture and the State agricultural experiment stations, wheat improvement gradually came to be more and more a function of State and Federal institutions.

More than 200 varieties of wheat are grown commercially. Five commercial classes have been established under the official grain standards of the United States, and these play an important part in enabling wheat to be classified as to value and quality. Wheat varieties have also been classified botanically and the distribution of the varieties in the United States has been mapped.

Superiority of germ plasm in wheat may be measured in three ways: (1) By the commercial acreage of varieties, which is a rough guide to what farmers have found most valuable; (2) by their relative performance in experimental tests designed to bring out comparisons; and (3) by the way they transmit desirable characters when used as parents in crosses. These methods are used to classify and evaluate many wheats as a basis for recommending varieties for growing in each of 40 different States.

The important steps in the improvement of wheat in the United States are marked by the use of three methods in turn—introduction, selection, and hybridization. The introductions of the late M. A. Carleton, of the United States Department of Agriculture, as a result

of plant-exploring trips in Russia, helped to establish the growing of hard red winter and durum wheat in the United States at the close of the nineteenth century. Chief among these introductions were Kharkof and Kubanka. Since about 1900, the Department has brought in more than 8,000 introductions of wheat. Nearly 5,000 of these are still available, as viable samples are maintained by growing them every 5 years.

The period around 1900 was marked by the appearance of the pure-line theory of Johannsen and the rediscovery of Mendel's law of heredity. The pure-line theory stimulated important work in the improvement of wheat by selection and breeding to fix desired characters. An outstanding wheat that resulted from this work is Kanred, selected by H. F. Roberts, of the Kansas Agricultural Experiment Station. Other important varieties developed by selection are Trumbull in Ohio, Red Rock in Michigan, and Forward and Honor in New York. Red Fife, which founded hard red spring wheat production and the great milling industry dependent on it, came from a few seeds of a wheat grown originally in Galicia, Poland. It became one of the parents of the world-famous Marquis wheat, developed in Canada by C. E. Saunders. Red Fife was also a parent of Yeoman, bred in England by R. H. Biffen, and of Federation, bred in Australia by the late William J. Farrer. These examples show how plant breeding, using germ plasm from any source in the world, cuts across national boundaries and develops products useful in the end to all men and nations. Of all wheat varieties, Marquis most truly may be said to have superior germ plasm. It has been a successful parent of many varieties, including Ceres, Hope, Reward, Reliance, Thatcher, Comet, and Tenmarq.

The late W. J. Spillman was a pioneer in hybridization work and developed four commercial varieties of club wheat in the State of Washington, the most important being Hybrid 128. The development of the rust-resistant Ceres by L. R. Waldron, of the North Dakota Agricultural Experiment Station, is one of the most successful examples of wheat improvement by hybridization. At the Minnesota Station, H. K. Hayes and his associates also have had marked success in breeding by hybridization; Minturki and Thatcher are outstanding varieties at the present time. Among other leading breeders who are doing much for the industry are E. F. Gaines, of the Washington Station, producer of the smut-resistant varieties Ridit and Albit, and E. S. McFadden, in South Dakota, breeder of Hope wheat, which brought into wheat from emmer, a different species, near immunity from stem rust.

Genetics is of increasing importance in solving the underlying principles of inheritance, and many of the characters and qualities of the wheat plant have been studied genetically, including the qualitative characters, color of kernel, and awnedness; the quantitative characters, maturity and winter hardiness; the disease reactions to stem rust and bunt; and quality characters important in determining economic value—protein content and baking strength.

Work has been done also in exploring the wheat cell and determining the ability of different species and genera to cross with one another. Some wheat breeders have made crosses between species and genera to study the possibilities of this method of breeding to obtain new characters of practical value. For example, from the

species *Triticum timopheevi*, or some other species or genus, it might be possible to secure, in bread wheat, complete immunity from stem rust, which would be even more valuable than the near-immunity of Hope wheat. This is only one of many possibilities for future practical breeding and genetic research.

BARLEY

Barley is an ancient crop, widely grown because it can make its way under extremely varied conditions of soil and climate, including some that would hardly support other cereals. The problems connected with breeding improved varieties are considerably affected by local needs. In Minnesota and Wisconsin, for example, lodging is more common than in the Great Plains region, and varieties that resist lodging are especially needed. Shattering is responsible for more loss under California conditions than under those prevailing in northern Illinois. Disease resistance is needed everywhere, but in different places diseases vary in their relative importance.

Barley is being improved by selections from mixed importations and mixed varieties, and new sorts are being produced by hybridization. The latter method is particularly valuable for improving strains by adding another character or correcting a defect.

The results secured by American breeders have been gratifying. More than 70 percent of the barley grown in the United States today consists of varieties produced by State and Federal workers. More than 9 million acres are seeded to improved varieties annually.

Since farmers would not grow these new varieties if they were not superior, the gain in annual income from this acreage is very large. Among the improved varieties are several smooth-awned sorts that are popular with farmers because they are easier to handle than the older varieties with a barb on the beard, and the straw is more usable. There are also superior selections of Oderbrucker, Manchuria, and Coast. Trebi and Club Mariout are high-yielding feed varieties that have found a useful place in the agriculture of certain areas. In all there are 16 improved varieties, each of which is seeded on more than 100,000 acres. The largest area devoted to a single improved variety exceeds 2 million acres.

The origin of Hero barley, not in itself an important variety, is an example of the way Federal and State cooperation works in plant breeding. A cross between Lion and Club Mariout was made at the Federal greenhouses at Rosslyn, Va., in 1912. Two generations of progeny were grown at University Farm, St. Paul, Minn., in cooperation with the Minnesota Agricultural Experiment Station. Several selections were made and these were distributed to a number of experiment stations in the West, including Chico, Calif., in 1915. The plant was grown at Chico through 1921 as 116. In 1922 the work was moved to Davis and the variety was grown as Hero. Later W. W. Mackie of the California Agricultural Experiment Station made a selection from this line which he distributed to California barley growers as Hero. It is obvious that this variety would not be in the hands of farmers today if any of these steps in Federal and State cooperation had been lacking.

The greatest asset of the barley breeder is his supply of parent material. The United States Department of Agriculture maintains a viable collection of more than 3,000 varieties. At any time it may be

necessary to turn to this collection to obtain a character of commercial value; for example, a new disease problem may arise where a parent of high resistance is needed. As long as extensive material is available, there is a probability of finding the needed parent. The Old World contains many forms of barley not yet secured by American breeders and it is essential that these should be obtained as rapidly as possible, especially since many of the forms in this rich reservoir of source material are continually being lost through economic changes.

OATS

Achievements in oat breeding include the development of many superior varieties now in commercial production, as well as new elite stocks available for further breeding. In the United States and Canada, a total of 75 improved varieties, developed by breeders, are commercially important at the present time, and these varieties are sown on 50 percent or more of the oat acreage of North America. Being higher in yield and better adapted to local conditions than the varieties they have replaced, they add materially each year to agricultural wealth. In countries other than those of North America, at least 64 improved varieties are important, including the famous Victory oat developed at Svalöf, Sweden.

In North America and abroad, many elite strains are available for further breeding. Among these, 145 American and 37 foreign strains may be considered the best. A high percentage of the new stocks available in North America carry resistance to diseases, such as the rusts and smuts, which is not true of the improved varieties in commercial production.

There are many possibilities for further improvement of oats through the use of the improved commercial and elite stocks. For example, the development of new stocks with the stem-rust resistance of Richland and the crown rust and smut resistance of Victoria has served to stimulate greater interest in the possibility of combining many desirable characters in one variety by means of hybridization. Again, the transfer of crown rust resistance from the Victoria and Bond varieties to the commercially important Red Rustproof and Fulghum types should result in an increase of from 20 to 30 percent in the yield of oats in the South, especially in those sections in which crown rust has been a limiting factor in oat production. The possibility of getting greater hardiness in winter oats by crossing with closely related species not belonging to the cultivated oat group is an almost totally unexplored field that deserves attention.

The first oat breeder connected with the Department of Agriculture was Jesse B. Norton, and the first pure-line selection and hybridization work appears to have been done under his direction from 1902 to 1907. However, a few years earlier the late M. A. Carleton introduced varieties of oats from Russia that became of great economic importance. C. W. Warburton, in charge of oat investigations in the Department from 1907 to 1910 and 1912 to 1921, first organized cooperative genetic and breeding investigations with the State experiment stations.

The Department has followed the policy of collecting material from abroad continuously. Usually where new varieties and other potentially useful material are brought to the attention of those in charge of the work, a request is made immediately for an experimental

quantity of seed. There are also standing requests to explorers and others traveling in foreign countries to send in samples if something unusual is observed. During recent years new unfixed as well as fixed hybrid material has been exchanged with plant breeders in other countries.

RICE

Rice is the chief cereal crop grown in certain tropical and semitropical regions, and it also extends into the temperate zone where conditions are suitable. In the United States, rice was first grown at Charleston, S. C., about 1685. Later, production shifted westward to Louisiana, Texas, Arkansas, and California.

In countries that grow rice for local consumption, the chief objective of breeding programs is high yield, but exporting countries are also breeding for improved milling and table quality because of their competitive value. In the United States, machine methods of harvesting make it necessary in addition to breed for resistance to lodging and shattering. Disease resistance is also an important objective. The methods used in this country have included introductions from abroad, pure-line selections, and hybridization of varieties.

S. A. Knapp in 1898 studied the rices of Japan as a plant explorer and brought in Kiushu rice. Introduction work has continued from 1900 to date, and altogether more than 7,000 introductions have been made up to the present. Introduced varieties that have been extensively grown in this country include Carolina Gold, Carolina White, Honduras, Wataribune, and Early Wataribune.

The commercial varieties now grown in the United States were developed by selection by the Department of Agriculture in cooperation with State agricultural experiment stations, and also by independent breeders. They include Blue Rose, Early Prolific, Edith, Lady Wright, Colusa, Caloro, Fortuna, Rexoro, and Nira.

Hybridization has not been employed long enough in this work to determine its possibilities fully, but the results obtained thus far are encouraging. Calady, developed in California, is the only variety produced by crossing that is ready for commercial production. There seems to be no reason why it should not be possible to develop by hybridization varieties that possess most of the characters desired by the producers, millers, and consumers.

The mode of inheritance of many characters of rice has been determined by research, and this knowledge is proving to be useful in practical breeding work.

Considerable progress in breeding has been made in the principal producing countries of Asia and elsewhere. The numerous native varieties have been collected and classified in several countries, inferior varieties have been discarded, selections have been made from the better varieties, and the best of these selections have been distributed for commercial growing. The increased yield from these selections runs from 5 to 25 percent more than that of the unselected parents. Improvement by hybridization is a more recent development, but it is the logical method to use when the possibilities of further improvement by pure-line selection have largely been exhausted. In Japan and India, important commercial varieties have been developed by this method.

CORN

Judging from a purely botanical standpoint, corn is one of the oldest, if not the oldest, cultivated crop plant. Its origin has been the subject of much speculation as it has no close wild relatives. The evidence seems to indicate, however, that corn probably originated in southern Mexico or Central America.

In spite of the fact that the white man has given attention to the improvement of corn by selection and breeding since its discovery, the corn plant of today is little different from the plant Columbus found when he first visited this country. The principal accomplishments of the white man have been the development of the present well-bred dent varieties and their gradual extension throughout the corn-growing area as a result of the selection of adapted strains.

The first corn work conducted in the Department of Agriculture, consisting of varietal tests, was begun in 1865, 3 years after the Department was organized. Breeding work in the Department dates from 1898, when several varieties were grown and crossed by H. J. Webber in his studies of xenia, or the immediate effects of pollen upon the resulting kernels. Genetic studies involving selfing and crossing were begun by G. N. Collins in 1906. Inbreeding and selection within inbred lines began under F. D. Richey and C. H. Kyle in 1916.

The recent development of most practical significance is the production of hybrid corn. This offers promise of greater improvements in the corn plant than any breeding method previously tried. Hybrid corn is the result of advances in knowledge of genetics, the science of heredity. It is an outstanding example of the influence of theoretical scientific research in revolutionizing the production practices of an agricultural crop. Although hybrid corn is of very recent origin, the hybrids already produced have established their superiority in productiveness and in resistance to wind, disease, insects, and other unfavorable conditions.

It is extremely fortunate that our most important crop plant should be the plant best suited to theoretical researches in the fields of genetics, breeding, and cytology. The corn plant has occupied a leading place in research work in genetic principles. The development of a satisfactory technique for studying the cell has made corn unusually well suited to cytological investigations and investigations in the border-line field of cytogenetics, or inheritance in relation to cell behavior. All of these advantages have contributed to the building up of a practical breeding program with a quicker response to new developments in theory, and they have enabled theoretical research to make a more concerted attack on practical problems.

Present accomplishments in the development of hybrid corn can be considered only as indicating the possibilities of this method of breeding. Unquestionably, hybrids superior to any now available will be produced as the breeding work progresses.

SORGHUMS

Native to Africa and grown there for many centuries, the sorghums are recently naturalized citizens in the United States. The camels of the plant world, their capacity for punishment in the form of

drought has made them extremely useful as a forage and feed-grain crop in regions too dry for corn.

One sorghum, broomcorn, was introduced by Benjamin Franklin, whose shrewd eye found a single seed on an imported broom.

The first importations came from Africa, and from China via France, in the middle of the last century. An Englishman named Leonard Wray got them established in South Carolina and Georgia in 1857, at the request of Horace Greeley.

For 40 years elaborate efforts were made to found a great sugar industry on the sorghums. Harvey W. Wiley was a leader in these efforts. Finally they were abandoned and the sorghums settled down to a less spectacular but worth-while career.

More than 80 varieties of sorghums are now grown commercially in the United States, and all of them were developed by selection and hybridization from the few varieties originally brought in. No later introductions have proved to offer superior material.

Observant farmers with a flair for plant breeding have played a signficant part in picking individual plants that later founded new lines. One useful hybrid was found and developed by a mail carrier. This has been possible because sorghums have a remarkable range of diverse characters; wide crosses occur under natural conditions, and apparently the plant is exceptionally given to mutations.

Scientific breeding with sweet sorghums began in the late eighties, and similar work with broomcorn and grain sorghum was undertaken about 15 years later. Federal and State experimenters have sought primarily to get earlier maturity; palatable white or yellow grain as against grain with a bad taste, as well as a dark color; dwarf types for machine harvesting as against types too tall for ready handling; improved forage quality; better production of sorgo or "cane" sirup; and resistance to lodging, drought, cold, insects—notably chinch bugs—and diseases.

The breeders have been signally successful in producing plants practically to order. Especially, they have made short plants, as in Dwarf Yellow, Double Dwarf, Wheatland, and Beaver milo, that would fit the combine harvester; changed the color of seeds, as in Sooner milo; adapted the plants to new environments, as in Dawn kafir; introduced disease resistance, as in Spur feterita; and produced a dual-purpose plant, as in Atlas sorgo.

There are now sorghums that have a productive capacity of 180 bushels of grain to the acre, and sorghums that can produce 16,000 pounds of cured fodder to the acre. Environmental factors keep average production far below these figures.

A good deal of genetic research has also been done, beginning in 1914, to trace linkage relations, determine the genetic factors that cause hybrid vigor, and work out the inheritance of resistance to diseases.

SUGARCANE

As used throughout the world, the term "sugarcane" includes thousands of distinct varieties belonging to five or more species of *Saccharum*. Representatives of all species under certain conditions develop inflorescences and viable seeds, although it was thought for a long time that sugarcane does not produce seed. Under the right conditions, the species freely hybridize in nature and there is evidence that they even cross with closely related grasses of other genera.

The great majority of sugarcane varieties in three of the species are unable to compete with natural vegetation, but two species can maintain themselves under natural conditions. These two wild species, *Saccharum spontaneum* and *S. robustum*, comprise many distinct varieties, the number of which cannot even be estimated as it is continually being added to by current collections in India, Malaya, the East Indies, and the Pacific islands. Of the thousands of natural or "original" varieties of sugarcane—as distinguished from the far greater number produced by controlled breeding—the majority appear to be hybrids resulting from natural crosses. Sugarcane is therefore a term which includes a great range of heterogeneous plant material.

There is evidence that the cultivated sugarcane varieties originated in southeastern Asia, the East Indies, and Melanesia, the area where the two wild forms mentioned are now found, and that the cultivated varieties probably were derived from these forms, and perhaps others that are now extinct. There is no evidence to show that wild sugarcane from which cultivated varieties might have been derived are present in the New World, or that sugarcane existed there prior to 1493, when it was introduced by Columbus.

The increasing importance of sugar in commerce and the change from subsistence to commercial types of agriculture, which introduced massive plantings of sugarcane and intensified disease hazards, were major incentives to improvement by breeding. The discovery in 1887–88 that sugarcane produces true seed which will germinate placed a tool in the hands of breeders that marked the beginning of modern methods and the use of controlled hybridization, as carried on by experiment stations in Java, Barbados, India, Hawaii, and the United States. The first result was the beginning of "nobilization"—successive crossing of wild with "noble" or cultivated sugarcanes to secure forms resistant to disease.

Sugarcane breeding in the United States began at Canal Point, Fla., in 1921. One of the first things accomplished was the saving of the sugar industry in the producing area in this country. The industry had been wrecked by mosaic disease, and it was set on its feet again by the development of disease-resistant varieties.

Beginning in 1928, the Department of Agriculture instituted a definite system of crosses for the purpose of building up breeding stocks of known constitution. The breeding program includes crossing, back-crossing, and selfing, accompanied by selection, in an effort to improve varieties of sugarcane without interfering with their behavior in hybrid combination. The plan is intended to accomplish this by combining the favorable factors from two or more varieties in a single variety.

In attempting to trace the inheritance of factors, resort is had to cytological study, using pollen mother cells and cells of the root tip for determining the chromosome number. Stimulated by the notable work of Bremer in Java, workers in the United States have examined hundreds of varieties cytologically. From studies thus far, it is deduced that the basic number of haploid or sex cell chromosomes in sugarcane is 10, but whether it is a primary or secondary basic number is an open question. All known species of sugarcane are forms with many sets; the simple diploid forms with 20 somatic or body chromosomes are at present unknown. In the case of species crosses

with most other plants, the chromosomes from both lines of descent double, but in sugarcane the chromosomes from one line double and those from the other do not. An exception has been found in the behavior of *Saccharum officinarum* × *S. robustum*, in which the chromosome number of the hybrids has been found to be less than the sum of the haploid number of one parent and the diploid number of the other. The explanation offered for this is based on the possibility of a rather close relationship between these two species.

SUGAR BEETS

All modern sugar beets are descended from the "White Silesian" beet, developed in Germany 150 years ago by F. C. Achard and Freiherr von Koppy in the first commercial attempts to produce sugar from the beet. Years of mass selection by European breeders since then have resulted in marked improvement in the sugar beet. Up to 1934 American growers had been dependent upon Europe for their seed supply. There are distinct limitations in the European product from the standpoint of meeting the particular problems of the American industry. Selection against certain disease factors, for example, cannot be accomplished in the seed-breeding centers of Europe, where the diseases, serious in America, either do not occur or are of minor importance. On the other hand, in the United States losses due to epidemic diseases are serious, and the outbreaks may jeopardize the crop or make it unprofitable.

Immediate breeding problems in this country are the development of curly-top-resistant varieties adapted to conditions in the Western States, and the development of leaf-spot-resistant varieties for use in the eastern areas where this disease is a factor. Practically untouched are the important phases involved in finding sugar-beet varieties having adaptation to particular soil and climatic conditions.

Early work in the United States followed the European patterns of mass selection. In 1914, W. W. Tracy, Jr., began selection and inbreeding of sugar beets. In 1925, he had several hundred strains, many of which were approaching uniformity of genetic make-up. The lines produced by Tracy and selections made in affected fields have been used as sources of material by G. H. Coons and Dewey Stewart in developing leaf-spot-resistant varieties. In 1929, Eubanks Carsner and D. A. Pack, using resistant individuals derived from commercial fields seriously affected with curly top, and other selections previously tested for resistance, produced the curly-top-resistant strain U. S. 1. Re-selections from the U. S. 1 variety appear to be superior to the parent and are now made available for general use as U. S. 33 and U. S. 34.

Cooperative experiments beginning in 1922, by the New Mexico Agricultural Experiment Station and the Division of Sugar Plant Investigations, Bureau of Plant Industry, showed that, by taking advantage of the mild winter conditions in the southwestern United States, fall-planted beets could be overwintered in the field and a satisfactory seed crop produced the following summer. This method eliminates all the hand labor of lifting, siloing, and replanting the mother beets. Within a year, the United States will supply 30 percent or more of its sugar-beet seed requirements, and in a few years it should be able to produce seed to supply its entire require-

ments economically and efficiently. As new, improved varieties adapted for American conditions become available, this seed industry will have even greater importance in bringing promptly to the growers the results of research endeavors.

Since sugar-beet breeding and seed production are definitely interlocking, commercial concerns and farmers must come to recognize the values to be derived from increased emphasis on beet-breeding work and the significance of the domestic production of the seed.

The advances made in many lines of sugar-beet breeding indicate that important contributions are being made by genetic research. Studies on the hybrid vigor shown in the first generation of hybrids between complementary inbred lines will be influential in directing the course of all breeding investigations with sugar beets. The possibility of finding valuable characters in the other beet species which hybridize with the sugar beet still remains to be explored.

COTTON

Cotton became a domesticated plant so long ago in the Old World and perhaps in the Americas that no lines of descent between cultivated and wild forms can be definitely established. Old World cottons, which have 13 chromosomes in their sex cells, perhaps originated in two regions, French Indochina and tropical Africa, and New World cottons, which have 26 chromosomes, also in two regions, Mexico-Central America and the Andes. Old World and New World cottons can be crossed only with extreme difficulty, and there is also a good deal of incompatability between the two broad groups in the New World. However, it might be possible to develop methods that would overcome these difficulties in crossing and provide the cotton breeder with many new possibilities for combining useful characters.

Almost as soon as European colonies were established in what is now the southern United States, they began to grow cotton introduced from the Old World and the Americas. At first this was for homespuns and other domestic uses. After the middle of the eighteenth century commercial production began and the poorer types of cotton began to be eliminated. Apparently the only species finally left, with the exception of sea island, was upland, a short-staple type which is supposed to have originated in the Mexico-Central America region. The early longer staple upland varieties may have come from crosses with sea-island and other South American cottons. The survival of upland was due to its hardiness in the Cotton Belt.

In the last half of the nineteenth century, private cotton breeders were active and numerous varieties arose through introduction or selection, but the outstanding results in the improvement of upland cotton have occurred since 1900.

Sea island cotton reached the southeastern United States by way of the West Indies about 1785. The finest types were developed on the islands off the coast of South Carolina, and apparently a very rigid type of selection was practiced from the beginning. The development of sea island cotton in the United States was one of the earliest and greatest achievements in the application of an art, as distinct from a science, of plant breeding to any crop in the world, but the industry was wrecked by the boll weevil.

Over 99 percent of the present American crop is of the upland type, and it is with this type that the problem of further improvement is concerned. During the course of the upland industry, some 1,200 varieties have been described or noted. As many as 425 varieties and strains have been developed by some sort of systematic breeding, but these have all come from a few outstanding types.

The development of the upland varieties has been the result of a great deal of work, particularly since the turn of the century, by private breeders, the Department of Agriculture, and the State experiment stations. In the main, three objectives, in addition to improved productiveness and quality, have been of major importance.

When the boll weevil invaded the Cotton Belt, it was necessary to have early, rapid-fruiting varieties that would escape the weevil attacks. These were developed by importation from Mexico and Central America, by selection, and by hybridization, and the new varieties were substituted for the older ones, at the sacrifice of staple length. Around 1900 cotton wilt became a serious factor and wilt-resistant varieties were developed by selection and by hybridization. The third main objective was to restore longer staple types to meet domestic manufacturing needs. Egyptian varieties were tried in the main Cotton Belt, as well as hybridization of Egyptian and sea island with upland, but both efforts failed. Selecting for longer staple among the upland varieties, however, was successful.

The American-Egyptian cotton industry in the Southwest dates from about 1900 when Egyptian cotton was first tried under irrigation. But though the irrigated valleys of Arizona and California are similar to the Nile Valley, progress was slow. Selection work was carried on, and in 1908 a new, better adapted type was recognized among selections from the Mit Afifi variety. This type was isolated and became the Yuma variety. Later the Pima variety was developed from a single selection from Yuma made in 1910, and it entirely replaced Yuma. Recently a hybrid variety has been introduced which is a cross between Pima and Sakel from Egypt. The establishment of American-Egyptian cotton in the United States was made possible by highly refined breeding methods. Further developments in breeding may enable American growers to produce economically the type of cotton now imported into this country from Egypt to the extent of $10,000,000 a year.

Meanwhile, cotton breeding in foreign countries has been advancing rapidly. The present cotton industry in Egypt began about 1820, and modern Egyptian types have resulted from mixtures or hybrids of the native type with imported sea island and South American cottons. Considerable progress has been made in improving cotton in Egypt since 1900. This is likewise true in India, China, the Union of Soviet Socialist Republics, Brazil, the Argentine, and other countries. The effort to become self-sufficient and to establish different trade balances since the World War has enormously stimulated cotton production abroad, and the breeders have accomplished the improvements that make this development possible. In most cases, types imported from the United States have been extensively used in foreign breeding-improvement work.

As a result, the United States faces a stronger competitive situation in the foreign market than it has in the past, and it would seem to be vital to give more attention to breeding in this country. The great diversity of upland cottons grown here is a major handicap. But the

fact that these numerous varieties and strains come from a few types indicates that efforts can be concentrated much more than they have been on these few, which should be capable of meeting all the needs of the Cotton Belt. Only by developing and growing, throughout the cotton area, a uniformly high-grade product just sufficiently diversified to suit the range of environments can the United States meet foreign developments. The cotton breeder can do his part of the work. The one-variety community plan, now rapidly spreading, is a promising step in the direction of unifying actual production of high quality cotton on a large scale.

FLAX

The flax plant is the source of two valuable products—fiber, from which linen is made, and flaxseed, the source of linseed oil. Linseed cake, the byproduct of oil extraction, is a valuable feed for livestock. In the United States flax is now grown chiefly for its seed, although fiber flax is produced to some extent in Oregon. The flaxseed-producing States are Minnesota, the Dakotas, Montana, Kansas, and California.

Flax has been grown since prehistoric times and the wild species from which it originated is not definitely known. At the time the pyramids were built it was already a well-developed crop. This long period of cultivation and selection in many countries has produced a large number of varieties and types available for breeding better varieties. Since 1914, over 900 varieties of flax have been collected by the United States Department of Agriculture.

The most notable advance made by flax breeders in the United States has been the development of disease-resistant varieties. Flax has always been subject to a serious soil-borne disease known as flax wilt. As early as the first century Pliny wrote: "Flax has the property of scorching the ground where it is grown and of deteriorating the very quality of the soil itself." It was not until 1900 that H. L. Bolley, then a young professor of botany at the North Dakota Agricultural Experiment Station, discovered the cause of flax wilt and began his classical work on the development of resistant varieties. This work of Bolley and his associates is one of the outstanding achievements in agricultural research and crop improvement, and it influenced work with other kinds of plants. Bison flax, developed by Bolley and his coworkers, can be grown on the same soil year after year without loss from wilt. It is now the leading variety in the United States, and approximately 2,000,000 acres, with a farm value of nearly $18,000,000, were grown in 1935.

The present problem in flax breeding for linseed production is the development of varieties having seed of a higher oil content combined with a high drying quality of oil. Formerly flaxseed was flaxseed and little consideration was given to the yield and quality of oil. Recent experiments conducted in the cooperative work between the United States Department of Agriculture and the agricultural experiment stations of the flax-producing States have shown that varieties of flax vary greatly in the percentage of oil in the seed and in the drying quality of the oil.

Intensive breeding experiments are now in progress at the Minnesota and North Dakota Agricultural Experiment Stations in cooperation with the United States Department of Agriculture to improve

the yield and quality of oil in flaxseed. Arny, working at the Minnesota Station, has shown that these characters are inherited, although the combination of high yield and high quality appears to be difficult to fix in a single variety.

In breeding fiber flax the chief considerations are high yield and fine strong fiber of good spinning quality. These qualities are varietal characters and probably are transmitted in crossing although the exact mode of inheritance has not been determined. Quality of fiber is a complex character and is influenced greatly by climate, soil fertility, and other conditions.

The inheritance of flower color, seed color, dehiscence of the boll, and other characters of the flax plant have been investigated in the genetic research of Tammes, Shaw, and other investigators.

TOBACCO

Tobacco and corn are two great gifts of the American aborigines to the agriculture of the world. Even in a period of slow communication, tobacco culture or at least the use of tobacco had spread pretty well throughout Europe and Asia within 25 years of its discovery in North America early in the sixteenth century.

Today there is a high degree of specilization in tobacco. The crop is divided into several quite sharply distinct types, based on the character of the leaf; and these types are used for different purposes and are produced in different areas. The types were gradually developed during 300 years of selection and growth under different conditions in the hands of farmers. The discovery of White Burley in Ohio in 1864 and the importation from Cuba of the Havana Seed variety played an important part in the development of the domestic tobacco industry.

Two things are of first importance in the tobacco-breeding situation. One is that tobacco quality is extremely elusive, depending on taste and aroma, which cannot be analyzed chemically or physically or even tested by laboratory methods. The other is that this quality as well as other characteristics of the plant and the leaf are strongly affected by environment. For reasons not throughly understood, two nearby fields with apparently similar soil may produce tobacco of quite different quality from the same seed. Methods of handling and curing have a similarly great effect.

Thus the tobacco breeder is unable to breed for improved quality because he cannot as yet pin down the factors that affect it; and in all his work he must be exceptionally careful not to have the results confused by the effects of environment and manufacturing processes.

Fortunately, present varieties of tobacco are satisfactory, broadly speaking, in both quality and yield. But there is a pressing need to improve tobacco from the standpoint of disease resistance. In recent times, tobacco diseases have been taking a heavy toll. Granville wilt, mildew, mosaic, wildfire, blackfire, black root rot, stem rot, root knot, and black shank are all menacing. In North Carolina alone, two diseases, root knot and wilt, cost growers $5,000,000 a year. In Pennsylvania, wildfire sometimes cuts the value of the tobacco crop in half.

Breeders in the Department of Agriculture and the experiment stations have been working intensively on this problem. Strains resistant to the various diseases are carefully sought. Methods are

being worked out for effectively testing resistance, and studies are going forward to discover how it behaves in inheritance. By hybridizing, resistant varieties are being bred, always with an eye to maintaining quality.

Thus, No. 301, developed by the Florida Agricultural Experiment Station in 1930, is a valuable parent for resistance to black shank; Johnson Resistant White Burley, developed by the Wisconsin station in 1922, for resistance to black root rot; Ambalema, developed by the Puerto Rico Department of Agriculture in 1933, for resistance to mosaic; No. 79A and No. 57, developed by the United States Department of Agriculture in 1935, for resistance to wilt and mildew, respectively.

Breeders have now reached the point where they must consider the possibility of developing plants resistant not to one disease but to several or all diseases at once. The whole program requires close coordination among all the institutions concerned.

Various other points are receiving consideration in breeding projects, notably suckering habit; size, shape, number, character, and spacing of leaves; earliness in maturing; and nicotine content. The last has received a good deal of attention from the standpoint of producing a tobacco plant with very high nicotine content that can be used to make nicotine sprays. These are very important in combating certain major insect pests. They are now made from tobacco waste, and the cost is high. *Nicotiana rustica* rather than *N. tobacum*—the tobacco used for smoking and chewing—is the most promising plant for this purpose. A variety called Brasilia has given yields as high as 200 pounds of nicotine per acre.

BEEF AND DUAL-PURPOSE CATTLE

Since the carcass itself is the chief product of their art, breeders of beef cattle are guided more by considerations of conformation and type than are breeders of any other class of livestock with the possible exception of swine. Reputations of herds, prices paid for breeding stock, and breeding practices are based largely on show-ring judgments of form and type.

Very little fundamental breeding research has been done with beef cattle. One reason has been the high cost of herd maintenance for such research. Another has been the lack of accurate practical measures of the characters of economic importance, and lack of knowledge of the genetic factors involved. Broadly, four characteristics, in addition to health and fertility, seem important—weight for age, proportion of body parts, quality of carcass, and efficiency in the use of feed. Progressive breeders, who do not follow ideals of type alone, practice a breeding system based largely, though somewhat indirectly, on these points. Their selections are made on the basis of good conformation and rapid gains. Research has shown that there is a close relationship between desirable conformation and carcass quality, and that the animal which gains fastest in the feed lot is likely to make the most efficient gains. Moreover, it is generally admitted that the finest specimens of the beef-cattle breeder's art in all the major breeds meet the consumer's desires very well.

Recent research indicates, however, that quality of carcass and efficiency in the use of feeds, though probably not antagonistic, are

rarely found in the same individual, and that cattle vary in efficiency as greatly as they do in quality. Shorthorn steers in Department experiments under the same treatment required as little as 373 days and as much as 533 days to reach a live weight of 900 pounds—a difference of 160 days. In one case full brothers showed a difference of 100 days in age at 900 pounds.

The geneticist's problem, then, is to develop strains of cattle or systems of breeding that will combine efficiency of feed utilization with quality in the same animal so as materially to raise the average of excellence. The problem appears difficult, for studies to date indicate that conformation is largely the result of the interaction of general factors, group factors, and specific growth factors affecting both muscle diameter and the linear development of the skeletion.

Meanwhile promising progress is being made in the development of strains of beef cattle especially adapted to certain areas, such as the Gulf coast region, particularly by crossing Brahman and Africander cattle with breeds of British origin.

A critical review of various plans for studying performance of beef cattle indicates the need for a simplified procedure which will obtain information on growth, feed utilization, and conformation for all animals, without recourse to slaughter.

With dual-purpose cattle, ideals are not so definitely established, and the range of expression is more varied, since efficient production of milk as well as meat of good quality are involved. Record-of-performance studies by the Department show that there is as great variation in efficiency of feed utilization and in quality of carcass as with beef cattle. Records of outstanding individuals indicate that a reasonable degree of beef quality and high production of milk are not impossible in the same individual, though the extent to which a high degree of excellence in both is possible has not yet been learned.

SWINE

Scientific work with swine in this country has been largely concerned with profitable feeding practices and improved sanitation, and valuable contributions have been made in both fields. In breeding there is a notable scarcity of fundamental projects, and considerable attention is given to characters of little or no economic importance. At the same time, there has been more effort to measure the actual performance of swine as a guide to breeding, and also more experimenting with breeding methods suggested by modern genetic research, than has been the case with some of the other classes of livestock.

Extensive research conducted by Sewell Wright of the United States Department of Agriculture on inbreeding guinea pigs showed that strains or families could be established which differed significantly in vigor, efficiency of feed utilization, and disease resistance. This suggests strongly that families "pure" or homozygous for these characters could be established by inbreeding in the case of larger animals. The significance of this is that such family traits, as distinct from individual traits, would be transmitted uniformly to progeny. The families or strains would be in the truest sense sources of superior germ plasm available for bringing together favorable lines of inheritance in desirable combinations. At the same time, the inbreeding serves another purpose in that it shows up undesirable

inherited traits which are otherwise concealed, so that strains carrying them can be eliminated. The inbreeding is often accompanied by loss of vigor, but this loss can be more than recovered by properly conducted cross-breeding.

This in a nutshell, and stripped of many ifs and buts, is the dynamic concept back of present-day plant breeding. For many reasons the field remains practically unexplored in animal breeding.

The work started with swine in 1922, as an outcome of the work with guinea pigs, is a beginning. Inbreeding experiments with a definite plan have been undertaken by the experiment stations of California, Iowa, Minnesota, Oklahoma, South Carolina, and the Department, usually with brother and sister or half-brother and sister matings, and the work is now well under way. The results so far show that swine are not at all homozygous in their hereditary make-up and often carry serious hidden physiological defects; that there are strains with sufficient hereditary vigor to withstand close inbreeding for at least five generations; and that close inbreeding in the hands of the experimenter quickly identifies matings with desirable hereditary characters. The loss of vigor that frequently accompanies inbreeding has also served to emphasize the importance of health and constitutional vigor in the development of profitable strains of swine.

Cross-breeding of inbred strains is the logical accompaniment of inbreeding, but little has been done as yet in this direction. However, cross-breeding even without inbreeding has some significance as a possible source of animals possessing hybrid vigor. In this form it has long been practiced by an occasional producer of market hogs, and it has been studied by a few research workers. The Minnesota Station has made an interesting effort in cross-breeding, using three breeds and crossing the first-generation hybrid females of two of them with boars of the third. The hybrid sows thus produced have farrowed 20 percent more live pigs and weaned 36 percent more pigs per litter than purebred sows, and the average weaning weight of the litters from the three-way cross has been 61 percent higher than for purebred litters. The pigs have accomplished small savings in feed requirements and a considerable saving in the time required to reach 220 pounds weight.

Another important breeding project involves the use of imported Danish Landrace swine for crossing with various American breeds for the purpose of discovering new combinations of germ plasm that might give superior hogs. The Department is cooperating with the Iowa and the Minnesota Agricultural Experiment Stations in this work.

A fundamental requirement in all breeding work is the accurate measurement of the characters desired and as much knowledge as possible about how they are inherited. Both are difficult to attain in the case of many classes of livestock. Denmark has been the leader in applying standardized measures of performance for desirable economic characters in swine-breeding work. The Danish system has resulted in uniform animals of high quality, as well as in increased efficiency in production; in 17 years the system has brought a reduction of approximately 17 days in the time required to bring pigs to market weight. Similar plans are in progress or have been tried in other countries, including an effort in a very limited way in the United States. The difficulty in this country, with its long distances and

widely varying local conditions, is to find a system of testing and recording performance that will be practical for general farm use and not too costly.

SHEEP

Sheep are classified roughly as mutton breeds and wool breeds, and the latter, according to the character of their wool, as fine wools, medium wools, and coarse long wools. The majority of sheep in the United States are included in six breeds, the Rambouillet, Hampshire, Shropshire, Merino, Oxford, and Southdown, the other breeds being represented by relatively small numbers.

Both mutton and wool, however, are major products of all breeds. There is a wide variation in character and excellence both among and within breeds.

Most of the research with experiment station flocks concerns feeding and management. The breeding practices used are in many cases much like those of successful commercial sheepmen, and there is great variation in the characteristics being measured and the methods used. The breeding work with Rambouillets in Texas, where daughter-dam comparisons are being made of the offspring of different sires, is outstanding. One important measure of a sheep's economic value that has been given little or no direct attention by the majority of experimenters is the quantity and quality of the ewe's milk, the most important factor in the rearing of the lambs.

Genetic studies by the New Hampshire Station and in England, designed to furnish information on the inheritance of good mutton form, indicated that there are important hereditary differences between fine-wool and mutton breeds. Constructive breeding research with characters of this kind will require large numbers of offspring and some sheep bred pure for various characters as test animals. There is an immediate need for a system of accurate measurements to replace visual judgments of type, condition, back, rump, and leg.

There has been a large amount of research with wool to determine its nature, its variations in character, and its suitability for different uses, but very little has been done toward making laboratory findings available to the breeder in a form that he can understand and use to measure and improve the wool production of his flock. Even the procedure for determining wool shrinkage is so slow and exacting that its use is impracticable for most breeders.

A device recently developed by the Department's animal fiber research laboratory makes possible an easy, rapid study of magnified cross sections of wool fibers as they occur in the fleece. Its use has uncovered some surprising variations in desirability and quality, particularly in uniformity of fineness of fiber, among our prize-winning sheep. Judging fleeces by touch and the unaided eye, as in the show ring, is not accurate in details that are essential.

Before the geneticist can make much definite contribution to the art of sheep breeding he will first have to obtain a description of characters of true importance and then determine accurate methods for measuring variations in their expression. The many characters in sheep offer an excellent field for experimentation and the development of uniformly higher quality. The best individuals we have today seem to serve their purpose very well, but the flock average is much below that of the best individuals.

HORSES AND MULES

The horse has not been the subject of genetic experimentation to any great extent because of the relatively high cost of the animals, their slowness in reproducing and maturing, and the complex and varied nature of their performance. Studs maintained by experiment stations are kept primarily for instruction in judging and for producing farm work stock.

Reproductive troubles present one of the major problems in horse breeding. On the average, the service of at least two and possibly three or four stallions are required for each colt produced. Months of time often elapse after service before it is known whether a mare is in foal, and cases of apparent sterility are discouragingly frequent. Within the past 5 years workers in many parts of the world have developed methods for early and positive diagnosis of pregnancy and for successful treatment of sterility. These methods are proving so successful, in fact, that precautions should be taken to prevent the perpetuation of lines inherently weak in reproductive capacity but made fertile by the new treatment with hormones.

The kinds of performance asked of horses vary with the type of animal and the use to which he is put. Among them are power, speed, endurance, versatility, beauty of form and action, courage, and intelligence. To correlate these extremely varied traits with physical characters that might indicate excellence in one or more of them is a huge task.

Judgments and measurements of excellence in horses are being made in such competitions as racing, endurance rides, polo, rodeos, dynamometer pulling contests, colt club competitions, and horse shows. Splendid performance records and numerous indications of remarkable ability to transmit such characters as speed are to be found in the history of these competitions.

An achievement of note in American draft horse improvement work has been a project in Indiana known as the Hoosier Gold Medal Colt Club. It has nearly a thousand members in 45 counties of the State and is creating increased interest in better horses as well as bringing to light apparently superior lines. Show-ring judgments, however, are used as the principal measures of excellence, and these have drawbacks. The winning animals are the achievements of a breeding art rather than a breeding science.

The stallion enrollment laws now set up in 22 States are also worth while. This legislation has brought about the elimination of many unsound and inferior sires formerly at stud for public service.

The mule, though as popular and in as great demand as ever, has even fewer active scientific sponsors than the horse, and the United States is facing a shortage of good jack stock. Jacks are noted for their fertility, jennets for their high percentage of sterility. This offers an interesting problem to both the geneticist and the physiologist.

POULTRY

Man has accomplished much in molding the chicken to his fancy, but much remains to be accomplished, particularly in breeding poultry for economic qualities and efficiency of production.

The achievements of the past are amply attested by the bewildering variety of standard breeds that have been evolved from the ancestral

races of the domestic fowl. Much progress has also been made in the development of high-laying strains, but it must be admitted, in the light of newer knowledge of breeding methods, that poultry breeders are merely on the threshold of the possibilities that lie ahead.

Egg production is one of the most important elements determining profit or loss from the poultry flock, and when an analysis is made of the methods employed by breeders in developing superior laying strains, it shows in a striking manner that the most successful method of selecting breeding stock is based on what might be called a three-P program: Production records, pedigrees, and progeny testing.

Each of these three methods of selecting breeders has its proper place, but in the present state of the poultry-breeding industry in the United States the progeny-test method is the most important. The majority of poultry breeders attach too much importance to production records. They assume that the number of eggs a female lays is an indication of her breeding worth but have to admit at the same time that many high layers have been poor breeders. A good pedigree is to be desired because the better the pedigree to the third generation the greater are the chances that the birds will be good breeders; yet many a bird with a noble ancestry has proved to be a dud in the breeding pen. The progeny test is the real test in determining the breeding worth of a sire and a dam. Progeny from superior sires and dams are more likely in turn to be superior breeders than the progeny of stock that has been selected on the basis of production records only, or on pedigree only, or on both production records and pedigree.

This is logical because the progeny reveal the genetic constitution of the sires and dams. Egg production is inherited and the most successful poultry breeders are those who select stock for future breeding purposes from among the best families rather than the best individuals. Poultry breeders are beginning to realize that there is more than meets the eye when they look over their birds to select future breeders. It is the concealed heredity of the bird that counts in breeding for increased egg production and such other characteristics as egg size, hatchability, and chick and adult mortality. The most successful poultry breeders also appreciate the fact that the most accurate index of the breeding worth of sires and dams is based on the performance of a random sample of their progeny and not on the performance of a few selected individuals. The birds that are culled may give more information concerning the breeding value or lack of value of a sire or a dam than the birds that are saved.

The greatest need of the poultry-breeding industry is a larger number of breeders more thoroughly informed concerning the fundamental factors involved in the selection of breeding stock for the development of superior strains. Superior germ plasm will become more abundant when more poultry breeders become better informed.

DAIRY CATTLE

It was a unique and tremendous undertaking to survey some 26,000,000 dairy cattle in order to determine what progress has been made in breeding for consistently good production and to discover, if possible, where the best germ plasm for producing ability exists. At the outset, it was necessary to restrict the study to herds in which records of production for a considerable percentage of the animals had been continuously maintained over a period of 8 or more

years. This excluded a great many herds in which progress may have been made in developing superior germ plasm but for which adequate data could not be furnished because of intermittent or selective record keeping. Also, lack of time and funds prevented many States from including all herds in which records have been kept over a period of years.

The surveys actually made covered nearly 1,100 commercial, college, and experimental station herds, though the data showed so little progress in breeding for some of these that they were put aside for later analysis, and data for others were received too late to be included in the published analysis. The number of herds represented in this Yearbook, therefore, is 707. These 707 herds had 4,302 sires that were analyzed. The sires had 29,570 tested daughters out of tested dams. The average butterfat yield of the entire group of daughters was 451 pounds as compared with 452 pounds for their dams.

Though educational organizations and institutions have for many years advocated record keeping for dairy cattle, the movement has never attained the momentum and volume that was to be desired. Herd owners who keep records have used them principally for culling low-producing cows. It has been estimated that in our dairy herd-improvement associations only about one-third of the cows produce enough to be profitable to their owners, another third just about break even, and the last third are such low producers as to lose money each year for their owners. In connection with this statement, it should be remembered that less than 2 percent of the total number of dairy cows is represented in herd-improvement associations and that these, together with the cattle being tested through breed organizations, are in all probability considerably higher producers, on the average, than the remainder of the dairy cow population.

Without a constructive breeding program that will bring about a general improvement in germ plasm from the standpoint of production, dairy farmers will continue to carry the burden of a large percentage of cows that do not possess the inherent ability to produce a sufficient amount of milk and butterfat to make them profitable. Culling out a few low-producing cows is not a corrective for this situation. The poor cows will always be there to cull unless a program of breeding is followed that will eliminate the germ plasm responsible for low production.

For the purpose of determining the progress made in each herd in developing germ plasm that is superior for production, the transmitting ability of each sire used in the herd was analyzed. This analysis of transmitting ability was based on (1) the percentage of increase shown by the sire's daughters over their dams in fat yield, milk yield, and fat percentage; (2) the percentage of the total number of his tested daughters that were better than their dams in these three items; and (3) an adjustment based on the level of production of the dams as compared to the average yield of all the cows in the herd. The sires were rated on this basis as poor, undeterminable, fair, good, or excellent, the last three grades all indicating that the sires so graded brought about improved production. Summary sheets are being sent to each herd owner who cooperated in the survey.

In a herd in which three successive sires were used that were rated as fair, good, or excellent, the females carrying crosses of each of the

three will possess germ plasm superior, for level of production and concentration of genes determining high levels, to that of the foundation cows, their own great granddams. A bull calf with one of these cows as dam and a sire rated as fair, good, or excellent would be much more likely to possess an inheritance enabling him to transmit high levels of production than would a bull calf out of one of the foundation cows.

Study of the data indicates that with each succeeding cross of a sire possessing an inheritance for high levels of production, the low levels of production are eliminated from his offspring as compared to preceding generations, and the higher levels of production are raised. Unfortunately, the number of breeders who have been able to select consistently good sires is relatively few. Many breeders have the misfortune to select sire after sire that rates as poor, and many others who use a good sire follow him with a sire that rates as poor.

Of the 4,302 sires that have been analyzed in the 707 herds, 48 percent had too few daughters with records to permit an appraisal of their inheritance; 7.9 percent were rated as excellent; 8.4 percent were rated as good; 10.6 percent were rated as fair; 3.5 percent whose daughters were very nearly but not quite as good as their dams were rated as undeterminable; and 21.5 percent were rated as poor. Thus, under the practice of selecting sires that has been followed in the better herds, only about one-half of the sires were used extensively enough to determine with any accuracy what inheritance they possessed, and only about one in four of the total number possessed an inheritance that could be gaged positively as good enough for improving the germ plasm of the herds in which they were used.

When in addition the sires that do possess superior inheritance are very often followed by sires that possess inferior inheritance, it will be seen why more rapid progress has not been made in improving germ plasm for high levels of production and why less than a third of the total number of dairy cattle are good enough producers to be profitable to their owners.

Nevertheless, the results of the survey show a gratifying number of herd owners who have made progress in improving the germ plasm of their herds. If they continue to use sires possessing superior inheritance, they should eventually breed herds that will approach purity in their germ plasm for high levels of production. These herds will become the sources of the superior germ plasm that will bring about a marked improvement in the producing capacity of the total dairy cow population.

Concerning the Use of Technical Terms in the Yearbook

AN EFFORT has been made to eliminate technical terms as far as possible in the major portion of each article, but the use of some technical words is necessary in any review of scientific work as comprehensive as this if the meaning is to be conveyed without long

explanations. Authoritative definitions of these terms are given in the glossary that immediately follows this foreword.

An excellent defense of technical terms is made by Agnes Chase in her First Book of Grasses. She writes:

> Words like hames, whippletree, terrets, and a hundred more, meaningless to the city-bred rider on a trolley car, are familiar terms to the farmer. Such terms as carburetor, accelerator, clutch, spark plug, or magneto, unknown a few years ago, are now understood by nearly everyone, and those who do not as yet understand these terms are by no means deterred thereby from buying (or wishing for) an automobile. Spikelet, glume, and lemma are words no more difficult to learn than are hames, crupper, or whippletree, carburetor, clutch, or magneto.

She quotes Mark Twain's description in A Tramp Abroad of how they hitch up horses in Europe as a good example of the confusion caused by failure to use technical terms:

> The man stands up the horses on each side of the thing that projects from the front end of the wagon, throws the gear on top of the horses, and passes the thing that goes forward through a ring, and hauls it aft, and passes the other thing through the other ring and hauls it aft on the other side of the other horse, opposite to the first one, after crossing them and bringing the loose end back, and then buckles the other thing underneath the horse, and takes another thing and wraps it around the thing I spoke of before, and puts another thing over each horse's head, and puts the iron thing in his mouth, and brings the ends of these things aft over his back, after buckling another one around under his neck, and hitching another thing on a thing that goes over his shoulders, and then takes the slack of the thing which I mentioned a while ago and fetches it aft and makes it fast to the thing that pulls the wagon, and hands the other things up to the driver.

The glossary that follows was published by the Journal of Heredity and is used with their permission. Preparing such a glossary is a difficult task, and each definition was subjected to the fire of many experts before it was put in final form. Certain terms that do not have a direct bearing on the text of the Yearbook have been omitted, but some others are retained, even though not actually used in the text, because they appear so often in the literature of genetics.

GOVE HAMBIDGE.
E. N. BRESSMAN.

A Glossary of Genetic Terms

Compiled from a Glossary Prepared by the American Genetic Association

A

ALEURONE—The outer layers of the endosperm of a seed, which appear as a layer or layers of thick-walled cells.

ALLELOMORPH—Mendelian characters are inherited in alternative pairs (or series). These alternative forms of a gene, which are located at the same point on each one of a pair of chromosomes, are called allelomorphs. Examples: Albinism (recessive), Normal pigmentation (dominant); Horns (recessive), Hornlessness (dominant). ALLEL, ALLELIC (adj.)—variants.

ALLOSOMES—Special kinds of chromosomes distinguished from the ordinary chromosomes or autosomes by certain peculiarities of behavior and sometimes by a difference in size or shape.

AMITOSIS—Division of the cell or nucleus not involving the formation of chromosomes or a spindle.

ANAPHASE—That stage of cell division during which the chromosomes pass from the middle to the ends of the spindle.

ASEXUAL—Not involving germ cells or fusion of nuclei; said of reproduction, or of an individual employing such a mode of reproduction.

ATAVISM—Reappearance of a character after a lapse of one or more generations.

AUTOSOME—Any chromosome except a sex chromosome. AUTOSOMAL (adj.).

B

BACKCROSS—Cross of a hybrid to one of the parental types.

BIOMETRY—Application of statistical methods to the study of biological problems.

BIVALENT—Referring to the homologous chromosomes united or associated in pairs.

BLASTOMERE—One of the cells formed as a result of the first few divisions of the animal egg.

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Blending inheritance—Inheritance in which dominance of either parental character is lacking. Genetic and biometrical methods have shown that this is due, in many cases at least, to the interaction of several multiple factors independently inherited.

C

Cell—A bit of protoplasm, usually containing a nucleus, which serves as a unit in the structure, physiological processes, heredity, and development of living things.

Centrosome—A minute body generally present in animal cells and in the cells of some lower plants, but not in flowering plants; usually near the nucleus, and related in some way to the process of cell division.

Character (a contraction of characteristic)—A term used, often rather vaguely, to designate any form, function, or feature of an organism. The mendelian characters of genetics represent the end product of development in which a definite gene, or genes, have a decisive effect. "The constant and unchanging thing, therefore, is the factor (gene) itself rather than the character, and the unity which Mendel observed lies rather in this underlying factor than in the visible, and perhaps variable, character which it produces."—Sinnott and Dunn.

Chiasma—"In the diplotene stage [one of the early stages of cell division] the chromatids are associated in pairs in such a way that in one part of their length two chromatids are associated but in another part each is associated with a different chromatid. The point of exchange [with the different chromatid] is termed a chiasma." (Sansome and Phipp, 1932.)

Chimaera—An organism composed of tissues of two genetically distinct types as a result of mutation, segregation, irregularity of mitosis, or artificial fusion.

Chromatid—Chromosomes frequently bear the foreshadowing of a future longitudinal division so that they appear to be made up of two parallel threads. These threads are the chromatids.

Chromatin—That part of the nuclear substance which forms the most conspicuous part of the nuclear network and the chromosomes, and stains deeply with the "nuclear" or basic dyes.

Chromomere—One of the chromatin granules, arranged linearly somewhat like the beads on a string, comprising the chromosome.

Chromonema—A fine thread of chromatin material from which arises the spireme thread.

Chromosomes—Dark-staining bodies visible under the microscope in the nucleus of the cell at the time of cell division. The number of chromosomes in any species is usually constant. The chromosomes carry the genes, linearly arranged, which control the development of mendelian characters.

Clon—A group of organisms composed of individuals propagated vegetatively, not by seeds, from a single original individual.

Collateral inheritance—A term used to describe the appearance of characters in collateral members of a family, as when an uncle and a niece show the same character, inherited by the related individuals from a common ancester. Collateral inheritance is characteristic of recessive characters which appear irregularly, in contrast to dominant characters which appear regularly in successive generations.

Conjugation—Side-by-side association (synapsis) of homologous chromosomes previous to formation of gametes.

Correlation—A relation between two quantities such that an increase or decrease of one is, in general, associated with an increase or decrease of the other. (The degree of linear correlation is measured by the correlation coefficient, r, which may range in value from -1 to $+1$.)

Crossing over—Interchange of segments between homologous chromosomes previous to the formation of gametes. The result is an exchange of linkage relations between characters associated in inheritance so that they appear in different offspring. See Linkage.

Cytology—The study of the structure, function, and life history of the cell.

Cytoplasm—The protoplasm of a cell exclusive of the nucleus.

Cytoplasmic—Pertaining to the protoplasm outside of the nucleus; said of inheritance dependent on the cytoplasm or on objects contained in it.

D

Deficiency—Absence or "deletion" of a segment of a chromosome.

Determiner—An element or condition in a germ cell, supposed to be essential to the development of a particular quality, feature, or manner of reaction of the organism, which arises from the germ cell. The word is gradually falling into disuse, "gene" and "factor" taking its place.

Differentiation—The process whereby cells and tissues become structurally unlike, during the process of growth and development.

Digametic—Having gametes of two classes, in particular a male-producing and a female-producing class.

Diheterozygote=Dihybrid.

Dihybrid—An individual which is heterozygous with respect to two mendelian characters.

Diploid—Having two sets of chromosomes. Body tissues of higher plants and animals are ordinarily diploid in chromosome constitution. See Somatic.

Disome—A chromosome set having paired members, as in normal somatic tissue.

Dispermic—Fertilized by two sperm cells.

Dizygotic—Originating from two fertilized eggs. Dizygotic twins are genetically no more similar than ordinary brothers and sisters.

Dominant—*A character possessed by one of the parents of a hybrid, which is manifested in the hybrid to the apparent exclusion of the contrasted character from the other parent (the recessive).* Thus in a cross of green- and yellow-seeded peas the first generation has yellow seeds. Yellow is dominant and green is recessive, being transmitted but not appearing in the presence of the factor for yellow.

Duplicate genes—Two or more pairs of genes (factors) having similar effects on one character.

E

Egg—A relatively large, inactive, usually yolk-laden germ cell produced by a female organism.

Endocrine secretion—A secretion which leaves the gland by diffusion, not through a duct.

Epigenesis—The concept of generation now accepted by biologists, which holds that the germ or embryo develops afresh in each generation through the interaction of genes and other protoplasmic components, in contrast with the theory once held that development was merely an unfolding of organs already microscopically present in the egg.

Epistatic—Characterized by the dominant action of a gene over another gene situated on a different chromosome or at a different place on the same chromosome. Ordinarily, "dominance" refers to the interaction of two or more genes located at the same point on a chromosome.

Equatorial plate—The figure formed by the metaphase chromosomes lying at the equator of the spindle.

Eugenics—The application of knowledge of heredity to the improvement of the human race. "The study of agencies under social control that may improve or impair the racial qualities of future generations, either physically or mentally." eugenic (adj.).

Extension factor—A factor (gene) which extends the action of a primary gene. Thus, in mammals, black or brown pigment, restricted chiefly to the eye, becomes "extended" throughout the coat in black or brown varieties.

F

F_1—(Pronounced eff-one). The first filial generation. The first generation offspring of a given mating.

F_2—The second filial generation. The first hybrid generation in which Mendelian segregation occurs. (See Segregation.) Produced by intercrossing or self-fertilizing the F_1. The inbred grandchildren of a given mating. F_3, F_4, etc., denote later generations from a given cross.

Factor—Same as Gene.

Fertilization—The union of a male gamete with an egg, a process requisite, in the higher animals and most plants, to the development of the egg.

Fission—Division of a one-celled organism into two equal parts in asexual reproduction.

G

Gamete—A reproductive cell of either sex; a sperm or ovum.

Gametogenesis—Formation of sex cells (gametes).

Gametophyte—That phase of many kinds of plants which bears the sex cells. A plant which bears sex cells. In lower plants the sexual and asexual generations alternate. In higher plants the sexual generation is an inconspicuous part of the plant. (See Sporophyte.)

Gene—(1) The unit of inheritance, which is transmitted in the germ cells, and which by interaction with the genic and cytoplasmic complex and the environment controls the development of a character. The genes are supposed to be arranged linearly in the chromosomes. (2) "The physical basis of heredity."

Genetics—The science of heredity, variation, sex determination, and related phenomena.

Genom—A chromosome set.

Genotype—The entire genetic constitution, expressed and latent, of an organism, in contrast to the phenotype. (See Phenotype and Latent.)

Germ cell—A cell capable of reproduction, or of sharing in reproduction, as contrasted with the somatic or body cells which are specialized for other functions. Or, more strictly, a reproductive cell that has undergone, or will undergo, or whose cell descendants will undergo, oögenesis or spermatogenesis before participating in reproduction.

Germplasm—The material basis of heredity, taken collectively.

Gonad—A reproductive gland, or group of glands; an ovary, testis, or hermaphrodite gland.

Gynandromorph—An individual of which one part of the body is female in construction, and another part is male.

H

Haploid—Single; referring to the reduced number of chromosomes in the mature germ cells of bisexual organisms. (See Diploid.)

Hemizygous—Presence of a given gene in one chromosome when the homologous chromosome has a deficiency for this gene.

Heredity—The resemblance, derived from the ancestry, among organisms related by descent.

Heterogametic—Producing unlike gametes (with respect to the sex chromosome). In the "X–Y" group of organisms the male is the sex with different gametes (heterogametic), producing *X*-bearing sperms and *Y*-bearing sperms in equal numbers. The female produces only *X*-bearing ova. In the "Z–W" group (including moths and birds), the female is heterogametic, producing *W*-bearing ova and *Z*-bearing ova; the sperm-cells all carry a *Z* chromosome.

Heteroploid—An organism characterized by a chromosome number that is not a multiple of the basic haploid number.

Heterozygote—An organism to which its two parents have contributed unlike genes with respect to any given allelomorphic pair governing contrasted characters, and which in turn produces two kinds of germ cells with respect to the characters.

Heterozygous—Containing both genes of an allelomorphic pair, or two genes of an allelomorphic series. Heterozygous individuals usually either resemble the individuals homozygous for the dominant character or are intermediate with respect to this character. They transmit the recessive gene to half their offspring.

Hexaploid—An organism characterized by having six times the basic haploid number of chromosomes.

Homologous—Chromosomes occur in somatic cells in pairs; the members of these pairs are spoken of as homologous chromosomes.

Homozygote—An organism whose parents contributed to it a similar member of any given pair of genes, and whose germ cells are therefore all alike with respect to the genes for that character.

Homozygous—(1) [An organism] formed by like germ cells. (2) An organism is said to be homozygous for a given character when all its germ cells transmit identical genes for this character. This is the most frequently used meaning of the term.

Hormone—The active principle secreted by a ductless gland, or other chemical controller of physiological activity produced by an organism.

Hybrid—The offspring of two parents unlike one another in one or more heritable characters. (2) A heterozygote. (3) Used for the broader categories as: *Numerical hybrid*, one whose parental gametes differed in number of chromosomes; *structural hybrid*, one whose parental gametes differed in the structure of their chromosomes.

Hybridization—The process of crossing organisms of unlike hereditary constitution, thereby producing F_1 offspring possessing genes for the traits of both parents.

Hypostatic—Nonallelomorphically recessive. (See Epistatic.)

I

Identical twins—Two individuals developed from the same fertilized egg. They are extremely alike and are generally (but not always) found in the same chorion before birth. Also referred to as monozygotic twins.

Induction—A change brought about in the germ plasm with the effect of temporarily modifying the characters of an individual produced from that germ plasm; but not of changing in a definite and permanent way any such germ plasm and therefore any individual inherited traits.

Interchange—An exchange of segments of nonhomologous chromosomes. (The term "segmental interchange" is used by Belling to include crossing-over but the two are conveniently distinguished.)

K

KARYOKINESIS—Same as mitosis.

L

LATENT—A term applied to traits or characters whose genes exist in the germ plasm of an organism although the traits are not apparent in the organism. See Dominant.

LETHAL FACTOR—A factor which renders an organism expressing it inviable or unable to live. Inheritable lethal mutations are recessive in their lethal effect, and must be homozygous to be fatal to the organism.

LINKAGE—Association of genes in inheritance, due to the fact that they are located in the same chromosome.

M

MATROCLINOUS—Resembling the female parent.

MATURATION—A process which germ cells undergo before they become functional, consisting usually of two cell divisions, during which the number of chromosomes is reduced to one-half that of the body cells.

MEIOSIS—The reduction divisions preceding the formation of gametes, in which the members of each chromosome pair separate, and the chromosome number in the resulting daughter cells is reduced to half the somatic number, as distinguished from ordinary cell division (mitosis).

MENDEL'S LAW—Mendel enunciated three basic principles of heredity: (1) Inheritance of character determiners (genes) as allelomorphic units, not as a blend; (2) dominance; (3) independent random segregation of allelomorphs in the formation of gametes and their random recombination at fertilization. As a consequence of these conditions a given allelomorphic pair of unit characters appears in a certain definite predictable ratio (3:1; 1:2:1; 1:1) among the progeny of a given mating.

METAPHASE—That stage of cell division in which the chromosomes are arranged in an equatorial plate ready for separation of their two halves (in mitosis), or of their paired members (in meiosis).

METAXENIA—Direct effect of the pollen on the parts of the seed and fruit lying outside the embryo and endosperm.

MICROSPORE—Pollen.

MITOSIS—Cell division involving the formation of chromosomes, spindle fibers, and the division of the chromosomes by a process of longitudinal splitting. Thus each of the resultant daughter cells receives a full complement of the chromosomes, which existed in the original cell before division. Also called karyokinesis.

MONOFACTORIAL—Controlled by a single gene difference (factor) in inheritance.

MONOHYBRID—The offspring of two parents differing in only one mendelian characteristic.

Monozygotic—Originating from a single fertilized egg cell, which in the course of subsequent development has given rise to two or more individuals. Twins (or triplets, etc.) of such origin are genetically identical.

Morphogenesis—The developmental history of organisms from egg cell to adult.

Mosaic—An organism part of which is made up of tissue genetically different from the remaining part. Mosaics are produced by mutations during development or by chromosome nondisjunction or in other ways. (See Nondisjunction.)

Multiple allelomorphs—The existence of more than two alternative forms of a gene. Any two members of a series of multiple allelomorphs may be allelomorphic to each other. A single individual having only the normal number of chromosomes can bear only two members of such a series.

Multiple factors—Two or more pairs of factors having a similar supplementary, complementary, or cumulative effect. In a broader sense, any factors working together to produce a single result.

Mutation—A sudden variation that is later passed on through inheritance and that results from changes in a gene or genes.

Mutual translocation—Reciprocal transfer of parts of two nonhomologous chromosomes. (Essentially crossing-over between nonhomologous chromosomes.)

N

Nondisjunction—(1) Failure of a pair of united (synapsed) maternal and paternal chromosomes to separate at the reduction division, both chromosomes of the pair going to the same gamete. (2) Failure of chromosome halves to separate in cell division, both halves going to the same daughter cell.

Nucleus—A highly refractive, deeply staining body of specialized protoplasm found within nearly all cells. The chromosomes are found in the nucleus.

O

Ontogeny—The developmental history of an organism, from egg to adult individual.

Oöcyte—A female reproductive cell during oögenesis, up to the time of the second division. Oöcytes are designated *primary* before the completion of the first division, *secondary* thereafter.

Oögenesis—The series of changes, including one or two divisions, which the reproductive cells of female animals undergo before they are ready for reproduction.

Oögonium—In animals—one of the early germ cells of a female prior to the beginning of maturation. In plants—the organ which bears the egg cell.

Outcross—A cross to an individual not closely related.

Ovum—An egg.

P

Parthenocarpy—Production of normally formed fruit with no seed or with empty seed. Two kinds are recognized by Winkler: Stimulative, through agency of pollination, insect injury, or other stimulative action; vegetative—wherein a sterile fruit develops without any other stimulation, as in the navel orange.

Parthenogenesis—The development of a new individual from a germ cell without fertilization.

Partial dominance—Capability of being produced to an intermediate degree when only one member of a pair of genes is present.

Pentaploid—An organism having in its cell nuclei five times the basic (haploid) number of chromosomes.

Phenotype—The organism as exemplified by its expressed characters, as contrasted with its genetic constitution (the genotype).

Phylogeny—The evolutionary history of a species, genus, or type.

Plasmosome—A true nucleolus of a cell.

Plastid—One of several kinds of protoplasmic bodies in cells, like the green bodies in plant cells, which are centers of chemical activity.

Polar bodies—Two minute cells cast off from the animal ovum during maturation.

Polyploid—Normal body cells of the higher plants and animals have two sets of chromosomes (see Diploid). Polyploids are forms having three or more of these basic chromosome sets.

Polysomic—Having more than two chromosomes of one type with the remainder of the chromosome complex usually diploid.

Polyspermy—The entrance into the ovum of more than one sperm, whether normally or pathologically.

Prophase—The stage in cell division prior to the metaphase, during which the chromosomes appear in the nucleus, following the resting stage.

Protoplasm—"The physical basis of life"; a chemical compound, or probably an emulsion of numerous compounds. It contains proteins which differ slightly in each species of organism. It contains carbon, hydrogen, oxygen, nitrogen, sulphur, and various salts, but is so complex as to defy structural analysis.

Pure line—A strain of organisms that is gentically pure (homozygous) because of continued inbreeding or self-fertilization, or through other means.

Q

Quadrivalent—Chromosomes associated in a group of four.

R

Race—A group of individuals having certain characteristics in common because of common ancestry—generally a subdivision of a species.

Recessive—See Dominant.

Reciprocal—Involving the same types of individuals, but with the the sexes reversed; said of two crosses, in one of which the female possesses the same characteristic as does the male in the other cross.

Reduction division—The division preceding the formation of gametes, in which the chromosome pairs separate, and the chromosome number is reduced to half the somatic number.

Replication—Multiple repetition of an experiment under essentially similar conditions to reduce the errors due to uncontrolled factors (soil, parasites, etc.).

Reversion—Appearance of a character possessed by a remote ancestor but not by recent ones.

Rogue—(1) A variation from the type of a variety or standard, usually inferior. (2) To eliminate such inferior individuals.

S

Secondary sexual character—A character dependent for its expression upon hormones of the male or female gonads, but having no direct reproductive function.

Segregation—Separation of the genes of a pair in the formation of germ cells, the two genes going to different gametes. Segregation is manifested in F_2 (and later hybrid generations) as a separation and distribution to different individuals of the Mendelian characters in which the parents of the F_1 hybrid differed. Often referred to as Mendelian segregation.

Selection—The choice (for perpetuation by reproduction) from a mixed population of the individuals possessing in common a certain character or a certain degree of some character. Two kinds of selection may be distinguished: (1) natural selection, in which choice is made automatically by the failure to reproduce (through death or some other cause) of the individuals who are not "fit" to pass the tests of the environment (vitality, disease resistance, speed, success in mating or what not); and (2) artificial selection, in which the choice is made consciously by man, as by a plant or livestock breeder, for characters of value to man.

Selfed—Self-pollinated.

Sex chromosomes—Chromosomes which are particularly connected with the determination of sex. In most animals the females have two *X* chromosomes and the males one *X* and one *Y*. The *X* and *Y* chromosomes are often visibly different in size or shape. In birds, butterflies, moths, and some fishes the male has two *Y* chromosomes and the female one *X* and one *Y*. To distinguish the two types of sex-inheritance the *YY* chromosomes in this latter case are sometimes symbolized as *ZZ*, and the *XY* as *ZW*.

Sex linkage—Association of a hereditary character with sex, due to the fact that its gene is in a sex chromosome.

Sex limited—Appearance (or expression) of an inherited character in only one sex, due either to sex linkage (*Y*-chromosome inheritance), or to differential dominance in the two sexes.

Sibling—One of two or more children of the same parents, but not of the same birth. (Usually used in the plural.) = Sib.

Somatic—Referring to body tissues; having two sets of chromosomes, one set normally coming from the female parent and one from the male; as contrasted with mature germ cells having a single set of chromosomes.

Sperm—The spermatozoön, spermatosome, or sperm cell of the male.

Spermatid—One of the two cells formed by second division in spermatogenesis. By transformation in shape the spermatids become mature spermatozoa.

Spermatocyte—A male reproductive cell during spermatogenesis up to the time of the second division. Spermatocytes are designated primary before and during the first meiotic division, then secondary thereafter.

Spermatogenesis—The formation of male germ cells.

Spermatogonia—Primordial male germ cells.

Spindle—A group of structures resembling threads, in the form of a spindle, formed in the cytoplasm of a cell during mitosis.

Spireme—Chromosomes in the slender, threadlike stage characteristic of the early prophase of cell division (mitosis). It is in the spireme stage that the chromosomes usually begin to split longitudinally, foreshadowing division of the chromosome at metaphase.

Sporophyte—Plants and lower animals exhibit various combinations of alternation of generations. A diploid, spore-forming generation (the sporophyte) produces spores which give rise asexually to an altogether different form, the gametophyte. These gametophytes produce sex cells which unite (fertilization) to initiate the development of a new sporophyte. In the higher plants the "plant" itself is the sporophyte and the gametophytes are rudimentary, having a brief but important part in the reproductive cycle—the pollen grain, and its later development into the pollen tube, representing the male gametophyte generation.

Sport—An abrupt deviation from type.

Synapsis—The conjugation or union in pairs of homologous chromosomes, respectively of maternal and paternal origin, to form bivalents; the primary step in reduction or meiosis. (Wilson.)

Syngamy—Union of the gametes in fertilization or conjugation.

T

Telophase—The closing phase of mitosis, during which the daughter nuclei are reformed and the mother cell divides into two daughter cells.

Tetrad—The quadruple group of chromatids formed by the association of the bivalent chromosomes in the later stages of meiosis. (2) The four granddaughter cells originating from the pollen mother cell or spore mother cell.

Tetraploid—An organism characterized by a quadruplication of the reduced primary chromosome number.

Tetrasome—An organism having four chromosomes of one type, the remainder of the chromosome complex usually being double (diploid).

Trait—A term often used as a synonym of "character."

Translocation—Attachment of a fragment of one chromosome to a nonhomologous chromosome, resulting in a new arrangement of genes.

Trihybrid—A hybrid heterozygous with respect to three pairs of Mendelian factors.

Triploid—An organism characterized by having three times the reduced primary chromosome number.

Two-factor inheritance—Some characters depend for their development on two hereditary elements (genes), both of which must be present to produce an effect.

U

Unit character—A hereditary trait that behaves as a unit in transmission, being capable of inheritance independently of other unit characters and determined by a single gene. Example: Green and yellow seed color in peas.

V

Variation—In biology, the occurrence of differences among the individuals of the same species or variety.

Variety—A division of a species; a group of individuals within a species that differ in some minor respect from the rest of the species.

W

***W* chromosome**—See Sex chromosomes.

X-Y-Z

***X* and *Y* chromosomes**—See Sex chromosomes.

Zoospores—Spores possessing the power of independent motion.

Zygote—The cell produced by the union of two cells (gametes) in reproduction; also the individual developing from such a combined cell.

***Z* chromosome**—See Sex chromosome.

Heredity Under the Microscope

By J. H. Kempton, Botanist, Division of Genetics and Biophysics, Bureau of Plant Industry

LIFE for the individual begins at fertilization, but the beginning of the individual is the end of a complicated chain of events in the cell that have gone forward with miraculous precision. Many of these processes can be seen with the aid of a microscope—or rather what is seen is the end result, for the cells are no longer alive and functioning when prepared for microscopic examination. The cytologist or student of cells must interpret a disconnected series of still views, the proper order of which he judges chiefly from experience, though sometimes by intuition.

Reconstructing the story of cell division by piecing together the views of dead cells through the microscope is a task not unlike that of attempting to understand a motion-picture drama after the film has been cut up into its myriads of separate pictures. To make the comparison more apt we should have to throw away most of the short scenes and shuffle the separated pictures. If the drama were not too complicated we still could get some sort of story by studying the individual pictures, but it might not be the same tale the unmutilated reel would have told.

However, the cytologist does not have an unlimited field for conjecture, because his interpretations, based on what he sees, must harmonize with the results of breeding tests planned to determine the principles of inheritance from the way characters are passed on from one generation to the next. Indeed, many cell processes cannot be seen at all but are inferred wholly from genetic experiments much as the physicist assumes the existence of the invisible proton, electron, or neutron because of the behavior of substances subjected to certain forces.

Many features of the activities going on within the cell were discovered first from observations of inheritance in a jar of pomace flies—also commonly known as fruit flies or vinegar flies or in the cornfield, and were afterwards verified visually by the cytologists in much the same manner as the planet Pluto was first found in the calculating machine, to be seen later in the telescope. Facts discovered by such experiments and then verified by observation would seem to be well established, but all knowledge is subject to revision

especially as regards interpretation. Nothing is final in science, and especially does this seem to be true in biology; for in biology nothing is as simple as it sounds and there are many gaps to be filled and many discrepancies to be harmonized. These are the things being investigated—the very breath of life of the investigator. Thus, when positive statements are made in this description, the reader must take it for granted that what is accepted today may not be accepted tomorrow.

All life is confined in cells, from that of the single-celled immortal amoeba to the complex aggregation of cells that is man. The body cells of all organisms are very much alike in their major structural features, but a man or a corn plant is not reproduced in the same simple fashion as an amoeba.

Among the single-celled forms such as amoebae, parents and offsprings are identical, even in age. Two amoebae are simply one amoeba divided in two. New life is not created by the division, which is merely a convenient method for this organism to expand at a certain stage in its development.

When nature contrived sex, the kind of immortality possessed by the amoebae was necessarily discarded and the problem of actually creating life anew with each generation had to be met. This requires a more complicated cell mechanics.

Throughout the life of an organism, the cells in its body continue to divide and reproduce themselves. This is the fundamental life process. During the period of growth, this dividing process furnishes the new tissue of the parts of the body that are developing. But when a plant or an animal reaches a certain stage in its development, it ceases the production of body tissue —technically called somatic tissue—except that required for repair purposes, and sets about to form reproductive tissue from some of the body cells.

Though the cells developed for reproduction are essentially like the body cells, there are certain vital differences both in their manner of formation and in internal details. These differences are part of the mechanism by which the animal or plant passes on its inheritance to new individuals.

A General View of the Structure of the Cell

TO understand something of what takes places in preparation for a new generation of organisms that reproduce by means of sex, some picture of cell structure is essential. Cells are not any more uniform in structure than automobiles. They vary in size from those of the bacteria that are on the very limit of microscopic visibility—and if the viruses prove to be living organisms, there are cells even below the limit of visibility—to nerve cells several feet in length. In volume they range from an infinitesimal nothing to that of the ostrich egg.

In general each cell has a wall lined on the inside with a clear jellylike substance called ectoplasm, enclosing a fluid in which are

suspended a variety of organized bodies, the whole being the protoplasm or living matter. The protoplasm or cell content is conveniently divided into two parts, the nucleus and the cytoplasm. The cytoplasm, though packed full of fascinating problems, is of only minor interest from the standpoint of heredity,[1] and will not be discussed here.

Embedded in the cytoplasm is the nucleus or cell center, which may be thought of as the cell's brain, since it controls the behavior of the entire cell. The nucleus, only a fraction of the cell in size, is a complicated entity, and well it might be, for it embraces all that the individual may become, whether a prize hog, a waltzing mouse, or a genius.

This nucleus is composed of a membrane enclosing a fluid in which are suspended extremely minute granules that have, among other qualities, a fortunate affinity for various dyes—fortunate because it permits them to be seen when they are properly stained. This propensity for absorbing stains led to their name, chromatin, from the Greek word chromos, meaning color. These chromatin granules undergo remarkable transformations at various stages of cell life, and since it has been found by experiment that they are the carriers of all inherited characteristics, their peculiar changes are worthy of intensive study.

In addition to these chromatin granules there is usually another darkly staining body, the nucleolus.[2]

As a cell reaches the stage for division, the chromatin granules collect together in threadlike bodies interwound in a living Gordian knot. When they are assembled in these threads they are known as chromosomes, literally "color bodies", as they still retain their thirst for dyes.

The number of these chromosome threads is practically constant for each species of living thing, no matter how specialized the cell may be in function.

There is the further regularity that in some groups of animals the females have one more chromosome than the males whereas in other groups this situation is reversed, the males having the extra chromosome. In these cases the odd chromosome, which can usually be identified by its shape, is spoken of as the sex chromosome, for it has been noted that it is always associated with maleness or femaleness, as the case may be. In some animals and in most plants, however, there is no difference in the chromosome number of the male and female sex.

FIGURE 1.—Chromosomes as seen in a body cell of a female pomace fly showing the sex chromosomes designated *XX*. (From Painter and Muller in Jour. of Heredity.)

But even where the number is the same in both sexes it is possible to identify so-called sex chromosomes in many animals. In mammals and pomace flies, for example, the females have two sex chromosomes designated *XX* (fig. 1) whereas the males have but one *X* and a mate called *Y*. In birds and moths, the females have two unlike sex chromosomes designated *WZ* while the males have two *Z* chromosomes. The presumption, then, is that the sex of the organism is largely determined by the kind of chromosomes originally present in the cell from which it grew.

[1] Ignoring the relatively few cases of maternal inheritance from the cytoplasm.
[2] The reader must keep in mind that this is a very general sketch of a cell. Almost every statement is subject to exceptions for some member of the multitude of different sorts of cells.

WHY GERM CELLS HAVE HALF AS MANY CHROMOSOMES AS BODY CELLS

But leaving aside this question of sex determination, each cell of every individual resulting from sexual union contains a double set of chromosomes, one set from the mother, the other from the father. Throughout the life of the individual these body cells continue to divide. In this process each chromosome is halved lengthwise and the two halves pass to opposite ends of the cell, whereupon the cell divides in the middle to form two cells. Nothing is more certain in biology than that in every cell of your body you have 24 chromosomes received from your father and another 24 chromosomes received from your mother. In this respect you are a double personality or most certainly would be were there not some means of compromising the contrasting traits of your parents.

When an individual reaches sexual maturity, the sex or germ cells are formed by a similar process of division, but in this case the number of chromosomes first has to be reduced to the number received from the father or from the mother instead of maintaining the number from both together. A reproductive cell always has just half the number of chromosomes that a body cell has.[3]

A moment's thought will suffice to show why this necessarily must be so. If the two sex cells that are to unite to form the new individual had as many chromosomes as the parents, the resulting organism would have the sum of the parental number of chromosomes in each of its body cells—24+24 in the case of man. The next generation would have 48 from the mother and 48 from the father, or 96. In each succeeding generation the number of chromosomes would be double that of the preceding generation, and in no time at all, relatively speaking, the world would contain nothing but chromosomes.

HOW THE GENES ARE INHERITED IN GROUPS

We all know, since the rediscovery of Mendel's epochal analysis of hybridization in peas, that the simpler characters of organisms, such as the red or white color of the wheat kernel or the polled character in cattle, have a basis in particles in the cell and the more complicated characteristics, such as milk production, yield of corn, or disease resistance, can be explained by assuming that combinations of certain of these particles are involved. These hereditary particles have been shown to pass from generation to generation without change, and when, as sometimes happens, they do change or mutate they go onward from their new condition as unalterable as before.

These hereditary elements have been called genes. The geneticists have noted another generalization with respect to genes, namely, that they are inherited in groups. Certain genes are found to pass together from one generation to another, that is, they are linked. It was observed that the number of groups of genes corresponded with the number of chromosomes in the germ cells of the organism. Thus Indian corn with 10 chromosomes in its germ cells has 10 groups of genes whereas the pomace fly, *Drosophila*—in which this gene grouping was first explained—with 4 chromosomes has 4 groups of genes.

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[3] Ignoring for the moment those organisms where one sex or the other has an extra chromosome which, of course, passes entire to one germ cell or the other.

The agreement between the number of groups of genes and the number of chromosomes strongly indicated that the genes were carried by the chromosomes from one generation to the next.

Actually the proof of this rests on even firmer ground. The identification of chromosomes has enabled the geneticist to prove visually that the genes are in fact carried by the chromosomes, even though he does not see the genes themselves. By subjecting dividing cells to X-rays it has been found that occasionally the groups of genes are altered. Genes that formerly were part of one group have become part of another (fig. 2). If the gene groups do in fact represent chromosomes, then in such cases the X-ray must have detached part of a chromosome, the detached piece then becoming attached to another chromosome. This is, indeed, just what happens, and a microscopic examination of the dividing cells of such an X-rayed organism shows clearly that one chromosome has been shortened by a certain amount and another increased in length by the same amount. Usually the attached piece can be spotted easily as it does not form a smooth union with its new associate.

FIGURE 2.—Chromosomes as seen in a body cell of a female pomace fly showing an X chromosome broken as the result of X-raying, the detached piece having become attached to one of the third chromosomes. (From Painter and Muller in Jour. of Heredity.)

In addition to the generalization with respect to groups of genes it was found as a result of much ingenious experimenting that the genes within a group are in a definite order with respect to one another. Thus if we have genes A, B, C, D, they will always be found in this order along the chromosome, never A, D, C, B or A, C, D, B. They have a linear relationship that, except for abnormal and rare breakages of the chromosomes, always remains the same.

HOW NATURE PROVIDES FOR FLEXIBILITY IN INHERITANCE

Now, although nature restricted the genes to chromosomes, a method was evolved for exchanging the contents of the chromosomes, received from the two parents, when the time came for the organism to produce germ cells. Had this not been done, the genes in each chromosome would have been transmitted to the germ cell in the same combinations in which they were received from the parents and few new arrangements could be given a trial.

To take an imaginary example: Suppose you are buying dried fruits at the grocery store. You have your choice of four kinds—apricots, prunes, peaches, apples—all done up in packages; but you can get only two packages at a time. In order to obtain variety, you buy apples and prunes this week, apples and apricots next week, apricots and peaches the next week, and so on. Still, these combinations are not varied enough, so the grocer agrees to take some apples out of an apple package and substitute some prunes, or exchange some of the peaches in a peach package for apricots. Now, though you still buy only two packages at a time, you get more variety.

This is crudely similar to what occurs in the sexual reproduction of an organsim each of whose body cells has four chromosomes, two from one parent and two from the other. Every germ cell formed

from such a body cell would receive two chromosomes. There would be a very limited possibility, as illustrated in figure 3, of breaking up and varying the combinations, as in the case of the whole packages of dried fruits. In an organism with a larger number of chromosomes—the corn plant with 10, for example—a larger number of new

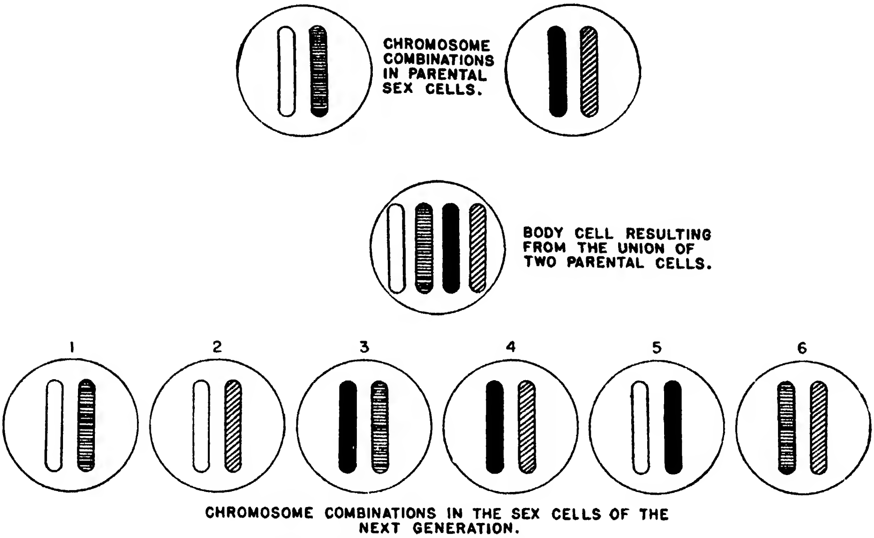


FIGURE 3.—Six ways of combining four chromosomes in pairs. Only four of these combinations are possible in the formation of sex cells, as combinations 5 and 6 are between homologous chromosomes. Combinations 1 and 4 are the same as those in the parents. Combinations 2 and 3 are the new ones, differing from those found in the parents.

combinations would of course be possible, even in dealing with the chromosomes as a whole; but still the possibilities would be limited compared with what could be done if there were a free interchange of the genes involved, which perhaps run into thousands. The ability to exchange genes between the packages or chromosomes brings about much more flexibility in securing new variations.

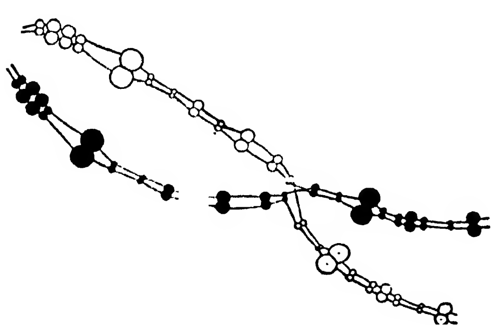


FIGURE 4.—Diagram showing how the genes are thought to be exchanged between paired chromosomes. (From Belling in Jour. of Heredity.)

This is what actually occurs in nature (fig. 4), though the exchange—called crossing over—is not entirely free. Cross-overs can only occur between contrasting genes, called alleles—for example, a gene for black and a gene for white; and consequently they can occur only between homologous chromosomes, that is, chromosomes similar in type. The whole mechanism of sex may be considered as a method for distributing genes among an interbreeding group of organisms and thereby testing many different combinations. The grouping of genes in chromosomes may be thought of as a brake on the freedom of combination.

The Formation of Germ Cells as Seen Under the Microscope

TO obtain the simplest picture of how the process of transmitting chromosomes and genes to the germ cells is carried out, an example may be chosen of the formation of the male reproductive cells. This sex, for a number of reasons, is the one most commonly studied by those cytologists who are interested primarily in the mechanics underlying the passing on of hereditary traits. For one thing, there are more male than female germ cells, so that the cytologist has more chance of finding the stages of division in which he is interested. However, he has studied enough eggs to know that from the standpoint of inheritance the same processes take place in the formation of the female sex cells, together of course with some others that have to do specifically with the development of eggs. Even had this study not been made, however, genetic experiments would force the conclusion that in so far as the sorting and separating of hereditary traits are concerned, the two sexes solve the problem in the same manner.

As a further restriction an example may be chosen from the plant world, thereby saving no little trouble in the technique of collecting and preparing the material, which in turn saves time in getting to the pictures. We shall, therefore, choose Indian corn.

HOW BELLING REVOLUTIONIZED THE PREPARATION OF MATERIAL

Let us follow the cytologist to the field. He already has learned at what stage in the development of the male flowers material must be collected if he is to catch the cells in the act of dividing, but for our purposes he must select material a trifle younger so we may see the show from the beginning. The trick is to get the dividing tissue killed instantly as it has been concluded that once a cell division has started it will rush through the process to the next resting stage.

When he examines his material, the cytologist will find cells in several definite stages but few indeed progressing from one stage to another, from which he concludes that the stages he commonly sees are resting stages or breathing spells between times of rapid action. He can deduce how the cell passed from one condition to another but he cannot watch the continuous process.

Having selected flower buds in the correct stage, and cleverly devitalized them in a deadly fluid, compounded for rapid penetration of tissues, his field work is over. He must now devote some time to removing the killing fluid and to staining, but he no longer need go through the laborious and time-consuming process of embedding the material in paraffin and cutting unbelievably thin sections for the microscope. Being a plant cytologist he has been saved all this by the discovery of the smear technique.

Now the smear technique is just about as it sounds, and it sounds far, far indeed from any process used by cytologists before its

discovery. The word "smear" simply was not in the cytologist's vocabulary, except possibly for use in referring to the preparations of confreres, and it has no place now in cytological studies except in its technical sense. For this short cut to the sort of cell studies demanded by the rapidly developing science of heredity, the cytologists are indebted to one of those too rarely appearing geniuses who, dissatisfied with current procedure, sweep aside all existing methods and start over. This man was John Belling of the Carnegie Institution of Washington.

Impatient of the necessarily slow results from the orthodox methods of embedding and staining, this investigator boldly attacked the problem of examining the workings of the sex cells by discarding the entire ritual of handling cytological preparations.

He crushed the anthers, which are the part of the male flower where division into sex cells takes place, onto a microscope slide with the first dissecting needle that came to hand. With the needle he skillfully smeared the contents of the anthers in an aceto-carmine dye and looked down the tube of his microscope to view the first chromosomes ever seen on the same day they were collected. At last there was a method for rapid inspection of the nuclear contents. But was there? An attempt to repeat the first success with additional material was a failure. Perhaps after all the old method of sectioning and staining—the laborious time-consuming technique—was essential. A lesser intellect or one with more orthodox training would have answered that it was, but not John Belling.

Step by step he retraced his actions, trying to duplicate the first results, but although hardly a motion varied, the chromosomes perversely refused to appear. Curbing his rising exasperation he examined everything minutely but could find no change in his technique except the needle used in dissecting. In his haste, in the first experiment, he had grabbed up the nearest needle even though it was a bit too pointed for the crushing action wanted. In the succeeding efforts a needle of more suitable shape had been chosen. To be sure, the second implement was of silver while the first was of common iron, but only a fool would consider that the contents of the nuclei would react to the sort of needle used upon them— only a fool and John Belling. Carefully he teased out the cells from an anther, using the iron needle; gently he smeared them about in the aceto-carmine stain. In a moment the cover glass was on and down the microscope tube peered the perplexed eye of Belling. He does not record whether or not he shouted "Eureka," but well he might have, for the configuration of the chromosomes was there before his eye in all its beautiful regularity.

A rapid method had at last been evolved for looking into cells. There is no need to inquire as to the functions of the trace of iron. Sufficient for our purpose to know that a trace of iron is essential before the chromosomes will absorb the aceto-carmine dye, and that the iron can be supplied satisfactorily by any ordinary needle.

We must now hurry on, for our first cells are on the microscope stage before us.

THE FIRST STAGE IN THE DIVISION OF THE NUCLEUS

If our material has been well chosen, without much trouble we shall soon find a satisfactory cell in the resting stage—in our case, a pollen mother cell. (The word "mother" here should not be confused with

sex; it means a cell from which pollen grains will originate.) Focusing upon the nucleus will show us a roughly circular disk filled with minute purple-black dots. These are the chromatin granules. Nothing less organized could be imagined, for they are distributed throughout the nucleus with about the same lack of order as the dust particles in a room where the rugs are being swept. Yet these disorderly particles are to determine a series of precise mechanical operations within the cell, after which, by uniting with a similar group from the female sex, they will produce a very orderly corn plant.

In addition to the fine granules we see a darkly stained circular body very much larger than any of the granules. This is the nucleolus, which remains one of the mysteries of cytology. All sciences have their unexplainables, their orphans, things that are pushed to one side because they seem to be meaningless. The nucleolus is now in this position, but in the future, as knowledge of inheritance develops, this mystery body may be more important. It is assumed, for example, that the hereditary elements that determine whether an animal is a sheep or a goat are transmitted by exactly the same means as the element that determines whether a sheep is to be white or black. It may not be so at all. Perhaps these less tangible things are transmitted by the nucleolus. But in such speculations we are in danger of going off the deep end so we had best return to our microscope.

The nucleus before us shows the beginning, the preparatory stage, of the series of cell events that will lead eventually to the orderly separation of these granules into four nuclei. Hunting around on our slide we soon find a cell in which the chromatin granules are not so completely dotted throughout the nucleus, and we observe that these cells contain what appear to be very slender threads scattered haphazardly around. These chromosome threads have already been mentioned in connection with our first general description of the contents of the cell. Their occurrence seems always to be associated with the disappearance of the chromatin as granules, and the cytologists have concluded that the chromosome threads are formed by the connecting of the granules. At any rate, the chromatin disappears as granules as the threads develop. This is shown in figure 5, where the outer circle represents the cell wall, the inner circle the nucleus, the large black dot the nucleolus, and the smaller dots the chromatin.

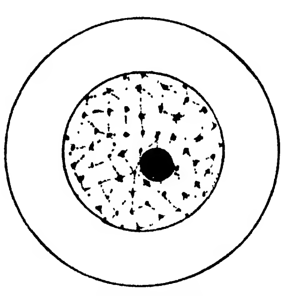


FIGURE 5.—Diagrammatic representation of a pollen mother cell previous to division. Being a diagram, it is rather more orderly than the view which would be seen in the microscope.

These tenuous filaments embrace some of life's most important functions. Just what causes the chromatic granules to gather into the chromosome threads, if indeed they do, is not known, nor is anything known as to how the process is controlled. There are good reasons to believe, however, that the tiny granules assemble in a definite order. Each is believed to be fashioned for a definite thread and for a definite place on that thread, but no machinery is visible capable of producing such exact regularity, and how the particles can order their own precise formations is another of the major mysteries.

The appearance of the thin threads, at any rate, is the first visible evidence of the organization of the chromosomes. These threads are the start of the process by which eventually the double set of chromosomes in body cells, one set from the mother and one from the father, will be fused, disentangled, and separated into two groups, each group to go to a germ cell that will have half the number of chromosomes found in the body cell from which it was derived. This process is known as meiosis, literally reduction, since the original number of chromosomes is reduced by half.

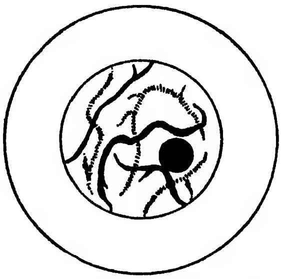


FIGURE 6.—The thin thread stage of the chromosomes at the beginning of cell division.

In hunting around over our slide we have seen in different cells a bewildering assortment of geometric configurations that to the untrained eye seem to defy orderly arrangement. However, they have been placed by cytologists in a logical series that gives a plausible picture of how the germ cells are developed.

If we look we shall find a nucleus in which all the chromatin granules have disappeared (fig. 6) and in their place there is an intricate knot of tangled threads. We should observe that the threads are single structures, for in the next view they will have doubled. By now we realize that the principal actors in the drama of cell division are these threads, and we may even sense that before the play is over they will appear in several disguises. Fortunately in the material we have chosen all acts are under way at once. We have on the stage before us a many-ringed circus, and while, as in the circus, confusion may seem to overshadow order, actually, as in the circus, the confusion is more apparent than real.

In turning to view our next ring (fig. 7) we find a nucleus in which the thin thread instead of being single is double, and to us it looks a little less tangled. We can find many nuclei in which the thread is double but none where other combinations occur—that is, there are no triple or quadruple threads. We finally conclude that this doubling has a compelling regularity about it that cannot be accidental. (In figure 7, for convenience in following the divisions, the chromosomes derived from one parent are shown as solid black lines and those from the other parent as broken lines. No such differences would be seen in viewing actual chromosomes.)

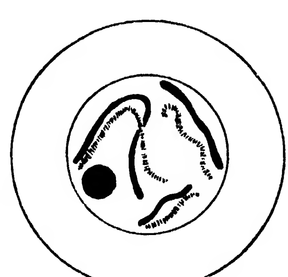


FIGURE 7.—The stage of cell division where the chromosomes from the parents pair.

Look as we will at the paired thread we can detect no differences between the two members. There is nothing we can see that aids us in interpreting this close association of threads, but breeding experiments offer strong proof that what we are witnessing is the fusing of the chromatin received from the two parents. It is generally agreed that the contacts between threads—known technically as chiasmas or crossed threads—represent the points where sections of chromosomes are being interchanged, with the consequent transfer of genes from

one group or chromosome to another. In accordance with this hypothesis it has been found that where, as in the pomace fly, there is no crossing over or gene interchanged in the males, chiasmas do not occur either. From breeding experiments it is known that sometimes such small sections of chromosomes are exchanged that only single genes are transferred, and at other times the exchanged sections may involve the transfer of many genes.

In the next view things are becoming less confused, for we are in the "thick-thread" stage. Instead of one pair of long threads, what we see now is a definite number of thicker threads (fig. 8). How they got into this condition we do not know; maybe they were separate all the time but were too entangled to be unraveled in the earlier stages. Since the plant we have chosen is corn, we can discover with the aid of the cytologist that there are 10 of these paired threads.

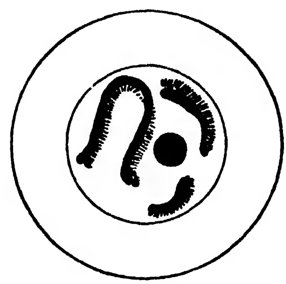


FIGURE 8.—The thick-thread stage in the division of the chromosomes. To avoid confusion, only six chromosomes are shown. In corn there would of course be 20 chromosomes at this stage.

We now see little spots that have failed to take the stain, and we are told that they are probably the points where the spindle fibers are attached. We shall return to these later. We note now that the points of attachment do not occur on the same places in all the pairs. Some are located near the middle of the thread, others nearer the ends, and the thought crosses our minds that these differences in location, if constant, would make it possible to identify some of the pairs.

In this stage, too, we see the first interest attached to the nucleolus. This spot has been with us constantly, doing nothing at all so far as we could see, but now we find one pair of threads is always attached to it and this, too, is a satisfactory indentifying mark.

We can also see very dark knobs (fig. 9) at various locations on the threads, and we should stop to make a further study of them. In figure 9 the large stippled region is the nucleolus, the black dots are the knobs. The spindle fiber attachment regions are shown as slightly stippled enlargements. The small black dots, regular in size, are known as chromomeres. We note that some threads have no knobs, and that the several threads do not have them at the same places. These knobs are very new to cytology, which has not yet reached even the speculative stage in determining their function on the chromosome,

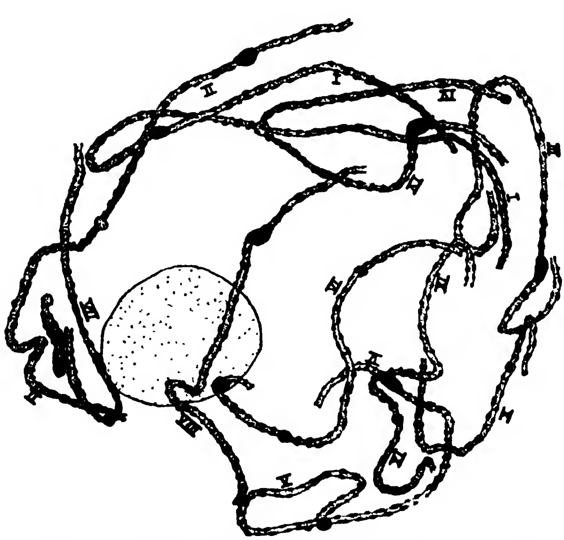


FIGURE 9.—Greatly magnified drawing showing the 10 paired chromosomes of corn.

but they are going to make history. In the meantime they provide excellent tags to mark the several chromosomes, and when a chromosome has been tagged it can be watched as an individual. This is a great advantage when the chromosomes have been operated upon by the use of X-rays.

FIGURE 10.—The twisted-thread stage in the division of the chromosomes.

But we are not watching our circus. In our next view the members of each pair of threads are twisted thoroughly around each other (fig. 10) like the connections made between two wires by an electrician. It looks rather confusing, but it may all be part of the condition in which the paired chromosomes exchange genes.

When we look for the next view we discover that in some of the nuclei the chromosome threads are not only untwisted, but each thread has become transformed into two. (This is apparent in the light-colored threads in fig. 11.) What was a pair is now made up of four strands. The threads have also become greatly shortened, and we can no longer distinguish the knobs.

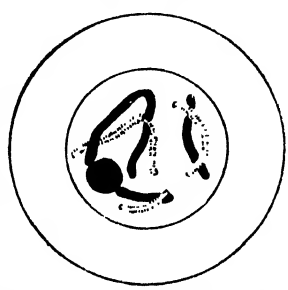


FIGURE 11.- The four-strand stage.

When we move the slide to view the next ring, we find to our astonishment that the nucleolus is gone, simply disappeared, and the wall of the nucleus is going too. What were threads now more nearly resemble sausages, which is enough of a transformation for anyone, so we shall refer to them from now on as chromosomes without the word threads. They occupy very little space and are in curious formations of rings and vees but are clearly pairs of pairs (fig. 12). It is difficult to imagine that they are the same bodies we saw spun throughout the nucleus in the early thread stages, but that is the most likely origin for them.

FINAL STEPS IN THE SEPARATION OF MATERNAL AND PATERNAL CHROMOSOMES

Our next view discloses a new feature. The nuclear wall has gone and the paired chromosomes are lined up across the diameter of the nucleus. They appear to be attached to tenuous fibers, the spindle fibers already mentioned. These fibers, which exceed the number of chromosomes, converge at two poles which have appeared on opposite sides of the chromosomes, in distance many chromosome lengths away. The whole arrangement is called the spindle, which it somewhat resembles (fig. 13).

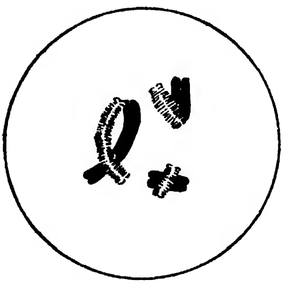


FIGURE 12.—The final stage before the division of the chromosome. The nucleolus has disappeared and the nuclear wall has disintegrated.

The poles, not conspicuous in themselves, appear to be centers of magnetic lines of force. Long lines of fibers extend fanlike from them, and we see that each chromosome is connected by a fiber with both poles very much like the toy monkey on a string.

In the spindle mechanism we again have a prominent cell feature, the origin and operation of which is unknown. True, in the animals,

there are bodies known as centrosomes, usually on the outer surface of the nucleus, that seem to be definitely connected with spindle formation, but cytologists can go no further than to record a seeming connection. Higher plants have no centrosomes, yet the same sort of spindles are found, sometimes with four or more poles, which eventually join together into two just like those before us.

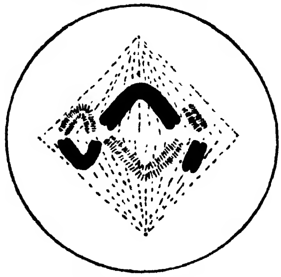


FIGURE 13.—The spindle.

This spindle formation is getting close, indeed, to cell dynamics. Not only do the spindles strongly suggest lines of force, like those shown when a magnet is held under iron filings scattered on a piece of paper, but, as we shall see, the chromosomes eventually travel along these lines to the poles.

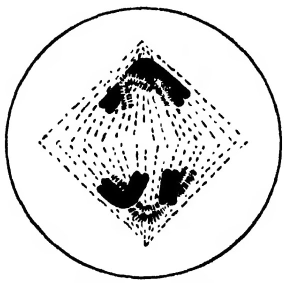


FIGURE 14.—The chromosomes have separated and moved to the poles.

Our next view shows the pairs of chromosomes separated but still double and on their way to the poles of the spindle (fig. 14). One member of each pair goes toward one pole, the other member to the opposite pole. So far as the chromosomes are concerned, division is over; they have paired and now they have separated.

In the final view of this first division, the chromosomes are well separated, clustered at the points represented by the vanished spindle poles. A line of dots marks the region where the fibers from opposite poles met, and along this line will form the cleavage, leaving a nucleus on each side of it, or two nuclei where we had but one before (fig. 15).

The process known as meiosis, or the separation of the maternal and paternal chromosomes, is now complete and each of the new nuclei contains half of the number of chromosomes present in the body cells.[4]

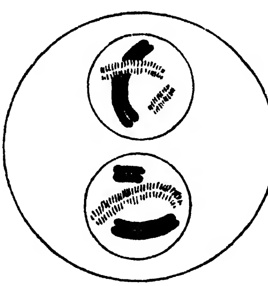


FIGURE 15.—The maternal and paternal chromosomes have separated and formed two nuclei, each with three chromosomes. These are shown as split foreshadowing the second division.

The different steps we have witnessed may be briefly summed up like this:

The chromatin granules disappear and in their place comes a thin tangled thread.

This in turn seems to be replaced by a definite number of paired threads (10 pairs, since we are dealing with corn). One member of each pair came originally from the mother, one from the father.

Each pair twists together, perhaps to allow the exchange of genes.

They untwist. A spindle forms, with a pole on each side of the cell.

The 10 pairs separate and 1 member of each goes to each pole. Thus each pole gets 10 chromosomes, half the full set of 20 in the body cell.

The poles vanish. Two nuclei form.

[4] It has been assumed that reduction took place in the first division and that the second division will be equational, that is, will leave the same number of chromosomes in each nucleus as before the division took place. This is not always the case, as the two processes may take place in the reverse order or some of the chromosomes may go through a reduction in the first division, while others in the same nucleus may be dividing equationally.

The cell divides between the nuclei, leaving 2 new cells each with 10 chromosomes.

The distribution of the chromosomes from the father and those from the mother to the new cells has been a matter of chance for the members of each pair, and this chance distribution allows for new chromosome combinations different from those that were received from the parents. In addition, some of the genes have been exchanged between chromosomes, which allows for still other combinations.

This is not the end of the dividing process necessary for the final formation of the germ cells, however. But now the steps are in reverse. The thick, short chromosomes in each of the new cells again become long, tenuous threads, and eventually granules of chromatin, as we saw in our first view. Having reached this second stage of breakdown the process already described begins all over again, though not all the steps are invariably repeated.

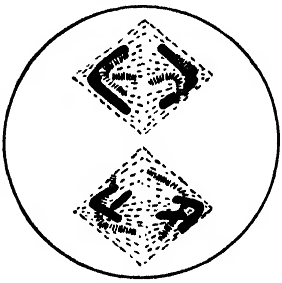


FIGURE 16.—The second division where each chromosome shown in figure 15 has divided. The halves have moved to opposite poles.

This second or final separation of the chromosomes (fig. 16), in the simplified example we have chosen, is an equational division; that is, it leaves the same number of chromosomes in each nucleus instead of a reduced number. Each chromosome is split in two lengthwise. Our second division is simply one by which these halves—these chromatids, as they are called—are separated to go to opposite poles of the spindle. On the completion of this second division (fig. 17), each new nucleus still has 10 chromosomes, just half as many as were present in the body cell that started the whole

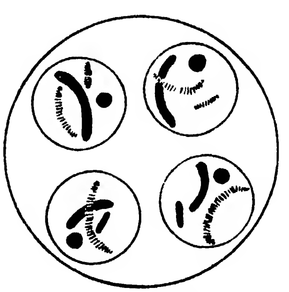


FIGURE 17.—Four nuclei resulting from the two cell divisions following the series of events shown in the preceding figures.

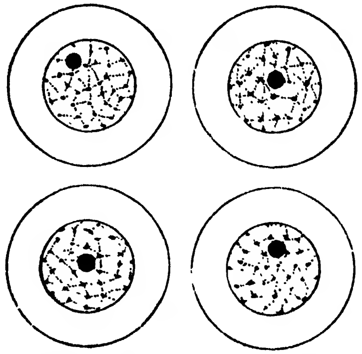


FIGURE 18.—The end result. Four cells o the tetrad that results from the division of the cell shown in figure 2.

process. This is called the haploid or simple number, while the number in the body cell was the diploid or double number.

The result of these two divisions is that there are now 4 nuclei and 4 cells, or a tetrad, each with 10 chromosomes. In our example, taken from the male sex of corn, each member of this tetrad (fig. 18) will become a pollen grain. This male germ cell will combine with a female germ cell which also has 10 chromosomes. The individual that results from the union will thus have 20 chromosomes or 10 pairs.

The Number of Chromosomes in Different Organisms

FROM the chromosome mechanism it should be possible to make the generalization that the greater the number of chromosomes the greater the variability. Given a fixed number of genes, then the more packages in which they are held, the greater the number of recombinations, for the maximum number of recombinations would be attained when the number of chromosomes equaled the number of genes. However, the facts do not warrant such a generalization. We may infer that the number of genes even in fairly restricted groups of organisms is not fixed and that some process for changing the number as well as the quality and combinations of genes must be in operation. In fact, the number of genes in two species of the same genus may differ by as much as several hundred percent. Thus in the genus *Triticum*, in which our common wheat belongs, there are 8 species—1 with 7 chromosomes, 4 with 14 chromosomes, and 3 with 21 chromosomes as their haploid or germ-cell number. It will be noted that the chromosome numbers are multiples of 7, and 7 is considered to be the basic number of chromosomes in this genus.

TABLE 1.—*Number of somatic chromosomes in some common plants and animals and in man*

Organism	Somatic chromosome number	Authority and year	Remarks
Animals:			
Man	48	Evans and Swezy, 1929[1]	
Cattle	60	Krallinger, 1927	
Chicken			Suzuki, 1930 gives 74[2], 73[3]; Hance, 1924-26, gives 36[2], 35[3].
Horse	60	Painter, 1924	
Sheep	60	Krallinger, 1931	
Swine	38	do	
Plants:			
Barley	14	U. Ubisch, 1921	40 varieties have been listed with this number.
Cotton	26, 52	Zaitzev, 1923	American cultivated cottons have the higher number.
Corn	20	Kuwada, 1915	Numbers above 20 are due to the presence of B-type chromosomes.[4]
Flax	30	Tammes, 1922	$2n$[5] = 18, in *Linum perenne* L. and some other wild flaxes.
Oats	42	Kihara, 1919	$2n$ = 14, 28, 42 in related wild species.
Rice	12	Kuwada, 1910	
Sorghum	20	Kuwada, 1915	Recently grass sorghums with $2n$ = 10, and $2n$ = 40 have been described.
Sugar beet	18	Winge, 1917	
Sugarcane:			
Saccharum officinarum.	80	Bremer, 1923	Variations occur in chromosome numbers of varieties of both these species.
S. spontaneum	112	do	
Tobacco	48	Winge, 1913	
Wheat:			
Einkorn group	14	Sax, 1921	
Emmer group	28	do	
Common group	42	do	

[1] The earliest author giving the established number is listed.
[2] Male.
[3] Female.
[4] B-type chromosomes are bodies resembling ordinary chromosomes but apparently without genes.
[5] $2n$ is the symbol used to designate the diploid number of chromosomes where n signifies the haploid number.

The species with 14 chromosomes are thought to have 2 sets of 7 chromosomes and those with 21, 3 sets, from which it follows that the species with 21 chromosomes has three times as many genes as the species with but 7 chromosomes.

Cytologists have revealed a bewildering assortment of chromosome numbers in the organisms they have studied and these do not seem to bear any relation to the larger aspects of the evolution of races of living things. It does not follow that the more chromosomes the higher the organism. Thus a man has but 48 somatic chromosomes while a rooster has 74 and one species of sugarcane has 112.

Among the higher organisms the smallest number of somatic chromosomes thus far found is 6, in the common weed hawksbeard, a species of *Crepis*, and about the highest number is 144 in *Althea*. Among the lower organisms, some of the fungi have but 4 chromosomes while another weed, the horsetail (*Equisetum*), has been reported to have 272, and even greater numbers have been seen in some of the other lower organisms. However, the difficulty of making accurate counts when chromosomes reach these high numbers makes their exactness open to question. All other organisms have chromosome numbers between these points. In table 1 there is presented the number of chromosomes in the somatic or body cells of several animals and plants—primarily those discussed in this Yearbook—as well as in man.

How Are the Mechanical Processes in the Cell Controlled?

WE have now completed our brief survey of the most characteristic configurations formed by chromosomes of corn as they went through the processes that reduced them from the diploid or body-cell number to the haploid or germ-cell number as a preparation for passing on their inheritance to a new generation.

Although the gene is the basic unit of inheritance, it should be noted that the fundamental process by which heritable traits are passed from generation to generation lies in the chromosome mechanism. The pairing, fusing, interchanging of segments, reduction to half the body-cell number, and final separation of the chromosomes is the mechanism by which genes are transmitted in an orderly manner. The random distribution of the members of the pairs of homologous chromosomes to the sex cells insures that the parental combinations of chromosomes will be broken up and new ones substituted in some of the offspring. The further refinement of the interchange of segments between like chromosomes from opposite parents assures that, though the ultimate unit of inheritance is a relatively unchangeable particle and hence not subject to blending, certain characters obtained from one parent can be tried in combination with certain characters from the other. This kind of recombination is responsible for many uncertainties and many adventures and achievements in the breeder's work.

The genes, of course, are merely speculative bodies—they are far too small to see. All that can be said is that the facts of inheritance are best explained on the assumption of some such particles, and the chromosome mechanism as seen through the microscope will explain the transmission of these particles from one generation to another in accordance with the observed results of breeding.

It would be unfortunate were the reader to gain the impression, from what has gone before, that knowledge of cell dynamics is restricted to the reduction division. All the absorbing problems of cell physiology, and the functions and operations of cell structures not immediately involved in reproduction, have been omitted in the preceding discussion for obvious reasons.

After having seen the stages and verified their regularity, the question naturally arises in our minds as to how these apparently mechanical events underlying life processes are ordered and controlled. The beginning of these processes may be considered to be the development of sexual maturity.

Just when an organism will reach this stage is fairly accurately known for a great number of cases. This knowledge has been acquired over the centuries by observation and is more definite for animals than for plants.

Since maturity is affected by environment and animals have attained control, of a sort, over gross environmental conditions, the variations in age at maturity in any given group of animals is due more to internal than external factors. We have no hesitancy in predicting that in man sexual maturity will be reached somewhere between 12 and 16 years after birth, the variation in age depending more upon the race and variety of man than upon his food and shelter. Sexual maturity in animals is connected in some manner with the secretions of internal glands, and the time at which the reactions will take place, though subject to some external control, is part of the heritage of the particular animals—that is, it is presumably one of the functions of the genes themselves to bring these reactions into play. The onset of maturity will go forward relentlessly unless, through some abnormal condition, the glandular system is interfered with.

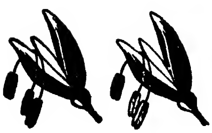
In plants, which have no control over environmental factors, many things affect the onset of sexual maturity. With a great many plants the length of day or the period the plant is exposed to light as compared with the time it spends in the dark affects the stage at which the organism reaches sexual maturity. This is not to say that under a given set of conditions plants do not have a stage for sexual maturity determined by inheritance, for, of course, they do. There are varieties of corn that produce sex cells 40 days after planting, while others require twice this time, but the time required can be altered by conditions outside the organism itself.

Once the organism has reached the condition known as sexual maturity, it will go through the almost mechanical processes we have been witnessing. That these processes themselves come under the control of genes is a fair deduction, but they might depend upon the reactions of the whole group of genes rather than upon a relatively few specific ones. However, in both plants and animals, genes have been discovered, and their positions on the chromosomes determined, which have definite and predictable effects upon the mechanics of cell division. These genes for controlling the behavior of the contents of the nucleus are as close as we can come to an understanding of what

governs cell events. These events are produced by specific genes. Nothing can be said as to how genes bring about these or any other of their known effects. That is a fundamental problem for research.

Nothing is known as to how the genes reproduce themselves, as they must, for millions of cell generations, and no amount of looking at cells is going to show us how this is done. Estimates have been made of the size of genes that lead to the belief they are about as large as the largest molecules. It would appear that they are at least as complicated as the most complex molecules. How a complex molecule can be divided and give two molecules exactly like the original is beyond comprehension, yet this process goes forward flawlessly for thousands of genes in millions of cell divisions.

Unusual Possibilities in Breeding



Some Results That Are Worth While or That Seem Promising

THE making of wide crosses between organisms that are only distantly related is one of the most fascinating aspects of the work done by the breeder of plants and animals. There has been a good deal of experimental work of this kind, and some of it has produced results that are worth while or that seem promising—as in the crosses between wheat and rye, sugarcane and sorghum, Africander cattle and domestic beef breeds. In most cases the hybrid proves to be interesting but not practically useful, like the offspring of the horse crossed with the zebra or the bison crossed with domestic cattle.

It has long been known that certain wide crosses are extremely difficult to make. They seemed to be "against nature," but just why this was so has not been understood until recently. Among the lower organisms, such crosses have been used experimentally to solve some of the secrets of inheritance. Among the higher organisms, they offer possibilities that in several instances may prove to be of unusual value.

There is no way to tell in advance whether two distantly related organisms actually will cross. The attempt must be made, and sometimes it must be repeated many times. Most scientists are guided by the existing classification systems for plants and animals, and formerly there were many crosses they did not attempt because the organisms were too far apart in the classification system. They thought this made the cross impossible. This article mentions several hybrids that were produced only because someone was bold enough to make the attempt and to make it with sufficient numbers to get results. It is to be hoped that more and wider crosses will be tried in the future.

The wide cross is not the only phenomenon that produces unusual results in the field of inheritance. There are mutations, for example, which bring about sudden changes in the germ plasm of a plant or animal. Just how this happens in nature is not known, but research workers have recently been able to induce such mutations in the laboratory by treating cells with X-rays, heat, and other forces. There is a possibility that this new kind of manipulation of the most basic factors in life may be another tool of great practical value; at any rate, it should give additional light on the nature of life processes.

Curious things occur like the breaking off of pieces of chromosomes—the particles in the cell that are responsible for passing on inheritance—that get lost or recombine with other pieces. The creeper fowl, which has short legs and wing bones, is perhaps an example of the results of such a deficiency in some section of a chromosome.

Perhaps, in nature, such things are accidents that happen in the best regulated organic processes. Then again, the cell may be thought of as a tiny but mighty laboratory where nature carries on her experiments, with the possibility that occasionally one will turn out to be worth while. Perhaps the development of sex, which made cross-fertilization possible in plants and animals, with all its incalculable effects, was just such an experiment in the beginning.

Wide Crosses and Unusual Characters Among Animals

IN THE sense that the crossing of the horse and the ass is not one of nature's ideas, the mule is a curiosity. Except in rare cases, mules do not reproduce themselves, and they would soon die out if they were not continually replaced by new crosses.

One of the exceptions is a fertile mule owned by the Texas Agricultural and Mechanical College. Her name is Old Beck (fig. 1), and

FIGURE 1.—Old Beck (*A*), Kit (*B*), and Pat (*C*). These three animals, owned by the Texas Agricultural and Mechanical College, are of interest because Old Beck, a fertile mule, produced the two foals, one mulelike and one horselike.

she arrived at College Station, Tex., in 1921, along with a colt that, according to the affidavit of the previous owner, she had foaled to the service of a jack in 1920. The foal, Kit, which looked like a mare mule, was bred several times but never foaled.

RECORDED CASES OF FERTILE MULES

Bred twice in 1921 to a jack, Old Beck failed to foal. But when she was bred to a saddle stallion in 1922, she again kicked over mule tradition by foaling a horselike colt, born September 26, 1923. This colt was named Pat Murphy.

Pat Murphy was of average size, strong, healthy, amorous, and a true horse in head, breast, hips, flank, and feet, and was highly intelligent. He had white stockings and a star on his forehead, like his father.

Old Beck was bred to a jack in 1924 and aborted at about 8 months. The foetus looked more like a mule than a horse, but it was deformed and had only one eye, in the center of its forehead. Subsequently, Old Beck failed to get in foal to repeated stallion and jack services.

The question is whether Old Beck was really a mule or a jennet. There is some evidence that bears on this point. (1) Her offspring from a jack was mulelike; her offspring from a horse was horselike. If she had been a jennet, the offspring from the jack mating would have been an ass; the offspring from the stallion mating would have been a mule. (2) Blood samples of Old Beck, of her first offspring, Kate, and of her later offspring, Pat Murphy, were tested by Dr. Sansteiner of the Rockefeller Institute for Medical Research. He reported that Old Beck's blood and Kate's blood reacted exactly like that of mules. Pat Murphy's blood reacted differently. Pat Murphy, incidentally is credited with five foals from mares. All were normal and horselike

It is probable that there have been more fertile mules than have been discovered. Dr. C. M. Morgan of Springview, Nebr., reports a fertile mare mule which has produced two foals by a stallion. A fertile Abyssinian mule was recorded in the Journal of Heredity (vol. 20, pp. 33–34, 1929) by Bashahaward Habterwold. The author remarks that the popular idea that wide crosses result in sterile hybrids is due in part to the fact that there is no great attempt to breed such hybrids.

Whether a strain of mules that would breed would have any value the scientist cannot know until he experiments and observes the results. At present, the production of mules is a more or less roundabout process, requiring the maintenance of two separate parental stocks—asses and horses. Jacks are fertile breeders, but jennets show a high and disappointing percentage of sterility, not yet explained. A breeding strain of mules might eliminate some of this difficulty; but at the same time there is a possibility that such a strain would not retain the hybrid vigor that is a very valuable characteristic of the mule. On the other hand, the establishment of a fertile strain would open up possibilities for the formation of new and possibly valuable character combinations.

The zebroid, the cross between the zebra and the horse, has been produced by various experimenters, but the hybrids have proved to be only interesting curiosities with no special economic value. Several

years ago the United States Department of Agriculture made an experimental cross between the zebra and the ass. The progeny were superior to either parent in action, conformation, and disposition, but they did not have any special commercial value.

WIDE CROSSES WITH DOMESTIC CATTLE

Wide crosses with cattle are not uncommon. The cattalo, a hybrid developed by crossing the American bison with domestic cattle, is intermediate between the parents in most respects, but has superior vigor and strength as does the mule. Several attempts have been made to establish a herd of these animals, but thus far no project has been very successful. The cattalo seem to have distinct commercial possibilities for certain regions but the production of a fertile herd is a hazardous undertaking. The chief difficulties appear to be high mortality of dams at parturition and the widespread occurrence of sterility among the male hybrids. From the results already obtained by different workers it appears that all of the first-cross hybrid males and most of those in the second cross are sterile. It seems doubtful, therefore, whether cattalo will ever be important in the cattle industry.

Another interesting hybridization experiment is the crossing of the yak—the ox of central Asia—with domestic cattle. In this cross sterility is apparently much less widespread. A hybrid with one-fourth yak blood makes a fair beef animal, but it seems to lack hardiness and therefore is not particularly useful in this country. In certain Asiatic countries the yak-domestic cattle hybrids are reported to have a definite place in economical meat production.

In its cattle-breeding experiments in the South, the Department has used the Brahman cattle of India and the Africander cattle of Africa on domestic beef breeds with considerable success. In semitropical countries an infusion of inheritance from one of the breeds native to the Tropics appears to produce animals better adapted to high humidity, high temperature, and diseases and insect pests characteristic of hot climates. The Brahman possesses the ability to perform well under conditions in which the European breeds of beef cattle cannot exist, and apparently it transmits to the hybrid offspring some of its ability to graze in intense heat and to resist insect pests and diseases. Considerable progress has already been made in the Southwest in establishing true-breeding strains of this cross.

UNUSUAL TRAITS THAT SHOW UP IN CATTLE INHERITANCE

A Holstein-Friesian cow in one of the breeding herds of the Bureau of Dairy Industry once produced twin calves, one of which was black and white, the other red and white (fig. 2). Both parents were black and white, and since they were registered animals, all their registered ancestors had been black and white. In the old days, the appearance of the red-and-white calf might have been explained on the ground that the mother had looked too intently at a red barn before the birth. In other breeds, such as the Aberdeen Angus, whose color is normally black, an occasional mating may similarly produce a red calf.

Actually, the red calf in these cases—and of course it need not be a twin—is what is popularly known as a throw-back. The explanation is that in their germ cells both parents carried a factor—probably received by the breed from an early red ancestor—that causes red color, as well as a factor that causes black color. The red factor happened to be handed on to this calf from both parents. If the calf had received a red from one parent and a black from the other, it would have been a black calf, because black in this case is "dominant" to red and covers it up. The red color is recessive. It might never be known that a bull or cow had a recessive red factor in its germ plasm unless it showed up in a mating in which both parents transmitted the gene for red.

FIGURE 2.—These twin heifer calves, one red and white, the other black and white, were produced in one of the breeding herds of the Department. Both parents were black and white and the appearance of the red-and-white calf is explained by geneticists on the basis that the parents each carried a recessive factor for red color. The red-and-white calf thus received a double dose of this factor.

It is never possible to be entirely sure what recessive trait there may be in the ancestry of an animal until some chance combination happens to bring it out. If a character of this type is undesirable, it is important to eliminate both the cow and the bull that carries it, and to test all their progeny, or the trait may show up in the herd again.

The "bulldog calf," common among Dexter cattle, is another example of a recessive character inherited from both the parents, but this one is lethal in its effects—that is, any offspring that gets the trait from both parents dies. The bulldog calf looks like a puppy and has a short head, stubby nose, and stubby legs.

Sometimes there is a shortening of the leg bones in cattle which gives them a squat appearance. In certain sections of the South, these animals have been called duck-legged cattle. They are re-

ported to take on flesh readily and to be easy to keep in good condition. There is reason to believe that this condition is due to one or more mutations in the germ plasm that affect the development of the skeleton.

A fairly common variation among cattle that affects the laying on of fat is found in this country as well as in Europe. The animals affected are characterized by bulging muscles, especially in the thighs, and by little fat.

The occurrence of a striking character known as "double muscled" in beef cattle has been found in a herd of Herefords in eastern Nebraska. These animals are abnormally thick and full in the thighs, with deep grooves appearing between the muscles. In addition, the rumps are often drooping and the twists—the hind part of the thigh where the direction of the hair changes—are lacking in depth and fullness. The hindquarters of these animals are striking in appearance. Packers refer to the type as "Yorkshires" and point out the lack of marbling, coarseness of grain, and lack of fat in the meat.

THE SHEEP-GOAT CROSS, AND SOME UNUSUAL TYPES OF SHEEP

An attempt to make a cross of the sheep with the goat was reported by Warwick, Berry, and Horlacher of the Texas Agricultural Experiment Station. The possibility of making this wide cross has interested experimenters for a long time and many reports have appeared concerning animals supposed to have resulted from the cross. Up to the present time, in the Texas experiments no living hybrids have been dropped, although partly developed foetuses (fig. 3) have been obtained. The workers have two possible explanations for the failure of the hybrid embryos to survive in the case of any of the 38 female Angora goats that were mated to rams, namely, that the genes of the two species differ too greatly in quality, or that the uterus of the mother is not suitable for the development of the hybrid embryo. The rams used have included one Rambouillet, two Merinos, and one first-generation hybrid between a Dorset and a Rambouillet.

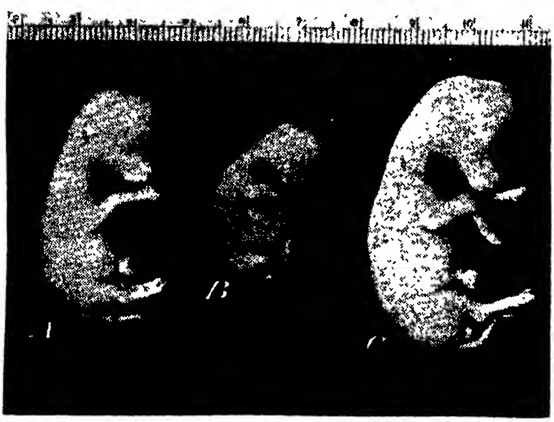


FIGURE 3.—Results of mating rams to Angora female goats: Embryos of Angora goat (*A*), goat × sheep (*B*), and sheep (*C*), each 44 days after mating. (From the work of the Texas Agricultural Experiment Station.)

At the South Dakota Agricultural Experiment Station an interesting experiment designed to develop a strain of tailless sheep is in progress. The foundation stock consisted of imported fat-rumped sheep from Siberia (fig. 4). These sheep were crossed with registered Shropshire, Hampshire, and grade Shropshire and Cheviot sheep. During the 22 years in which the experiment has been in progress,

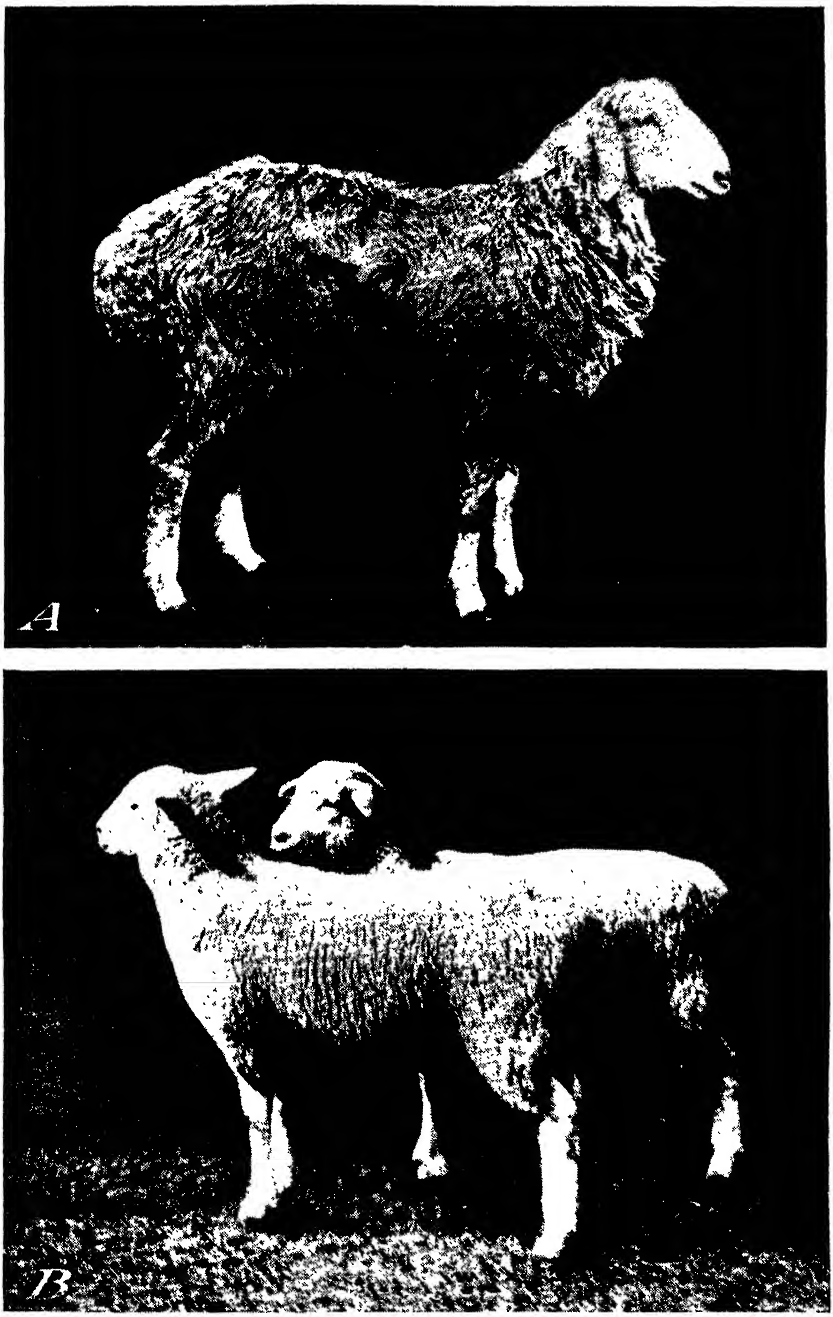


FIGURE 4.—*A*, Imported fat-rumped ram from Siberia; *B*, two of the 1934 ewe lambs, showing the tailless character. (From the work of the South Dakota Agricultural Experiment Station.)

there has been developed, through selective breeding, a strain in which a high proportion of the lambs are born either tailless or with very short tails. In the lamb crop of 1934, for instance, there were 59 lambs born, of which 22 were tailless, 18 had tails 1 inch or shorter, 10 had tails between 1 and 2 inches long, and the other 9 had tails over 2 inches long. At the same time the quality of the fleece has been materially improved over that of the foundation fat-rumped rams.

Figure 5 shows the remarkable fat-tailed sheep native to China. Unlike the tailless sheep, this breed has not been utilized in crosses in the United States.

FIGURE 5.—Fat-tailed sheep of China, native to the Chili, Shantung, and Honan Provinces. The tail is composed chiefly of fatty tissue, which is greatly relished by the natives, who use it as a substitute for butter.

MANY VARIETIES OF CHICKENS

Among chickens a great diversity of forms has been produced, witness the large number of recognized breeds and varieties. For example, there are 11 different varieties of Leghorns listed in the 1930 edition of the American Standard of Perfection for Poultry. The varietal differences are based on plumage colors and patterns and comb characteristics. The breeds show wide variations in size, from the standard weight of 10 to 13 pounds for hens and cocks of the Jersey Black Giant breed to less than 2 pounds for bantam breeds, and in characteristics of form, from the clean-cut gamelike conformation of

the Cornish fowl to the shagginess of the Sultan with its crested head, muff, beard, vulture hocks, and profuse shank and toe feathering. Frizzle, creeper, and rumpless fowls also represent types in which unusual genetic factors are expressed.

Various factors in the germ plasm of poultry, some dominant and others recessive, produce rose comb, pea comb, walnut comb, naked

FIGURE 6.—A chimera in chickens—a 50-50 bird, half one variety and half another. The left half (*A*) is Barred Plymouth Rock; the right half (*B*) is Light Brahma. The left leg is longer than the right leg.

neck, frizzle plumage, silky plumage, and frayed feathers. These and other characters are listed in table 1 of the article on poultry. Chimeras (fig. 6), or birds truly mixed in appearance, half one variety and half another, are unusual.

Among the Hamburghs and Campines there are males with male plumage and males with female plumage. In a classic case, a Buff

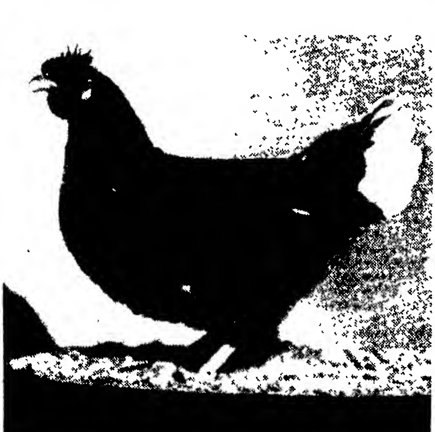


FIGURE 7.—To produce a bird with red body plumage and a white tail, cross a White Leghorn and a Rhode Island Red and then cross one of the hybrid cockerels with a Light Sussex female.

FIGURE 8.—These birds are hybrids secured from a cross between Bantam chickens and pheasants.

Orpington hen changed her sex completely. Up to 3½ years of age she was a normal, egg-laying hen. After that age she became a cock and the father of two chickens. Post-mortem examination showed that tuberculosis had destroyed the ovarian tissue, and male organs

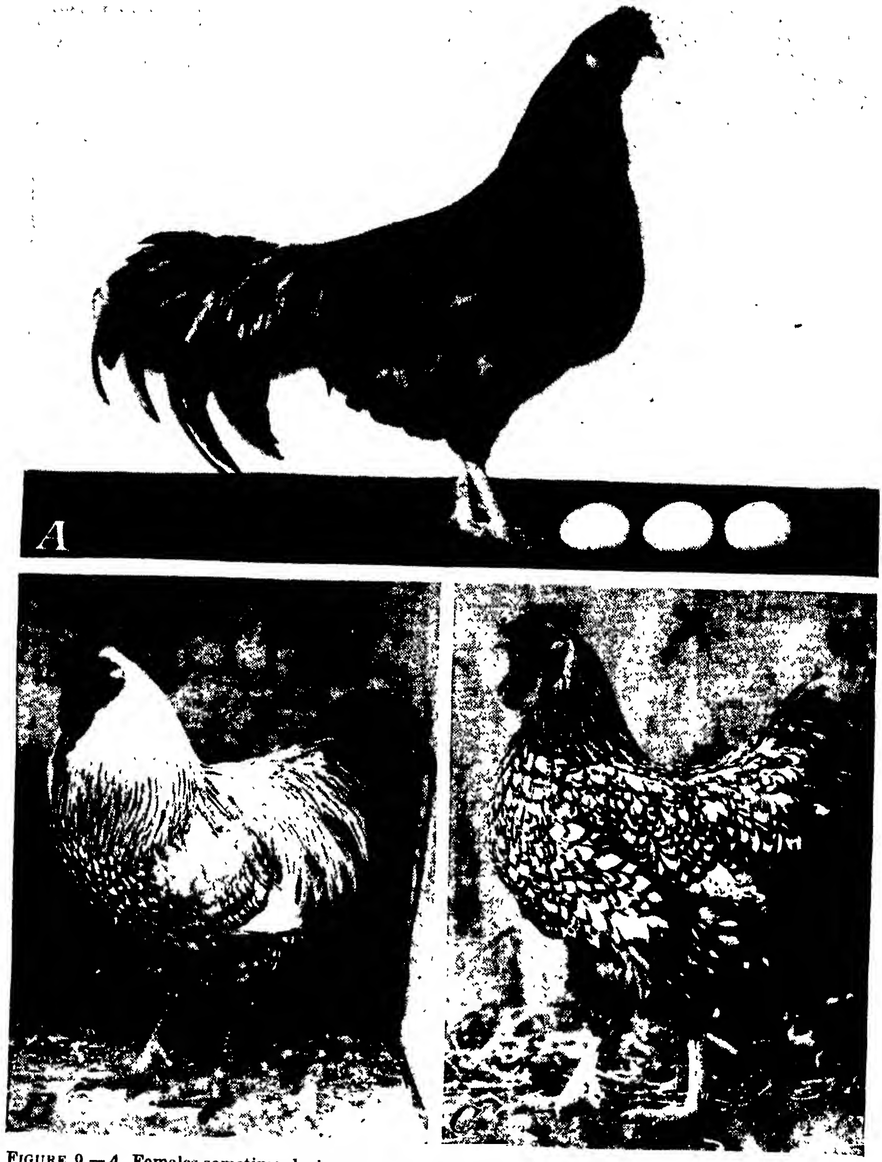


FIGURE 9.—*A*, Females sometimes look very much like males. When the ovaries are removed or become abnormal through the influence of disease or otherwise, cock feathering is sometimes assumed, as in the female shown above. After molting she acquired normal female plumage (after Cole). *B*, a normal or cock-feathered Silver Laced Wyandotte male. *C*, a hen-feathered Silver Laced Wyandotte male.

had developed. Investigation of such abnormal cases has thrown considerable light on the genetic basis of secondary sexual characters in fowl. Figure 9 illustrates some of these peculiarities.

The blue Andalusian fowl is a classic often used to illustrate principles of genetics. It is the recognized type of the Andalusian, yet it does not breed true. To produce a blue Andalusian, it is necessary to mate a black with a blue-splashed white. All of the first hybrid generation will then be blue, but if these blues are mated

together one-fourth of the second generation will be black, one-half blue, and one-fourth white splashed with blue. This segregation of types is common in the second generation of crosses. Another example of an unusual bird produced by crossing is given in figure 7.

Wide crosses, as between bantam chickens and pheasants (fig. 8) and between very different varieties of a group, have produced striking and unusual birds.

Exploring Unusual Possibilities in Plant Breeding

IN THE case of plants, new experiments with wide crosses between species and even between genera are now arousing a great deal of interest among breeders, though with genus crosses the work has in few cases been done on a large enough scale to determine the real possibilities. Wide crosses commonly give sterile hybrids, and in some cases thousands of these hybrids must be grown to find a single one that will produce seed to carry on the work. In spite of many difficulties, however, enough has been done to make plant breeders feel that this is a worth-while field for exploration. The significance of the work lies in the possibility of producing plants different from those now existing.

BREEDING NEW CHARACTERISTICS INTO WHEAT

For example, in the case of wheat, it would be desirable to have plants with greater tolerance to unfavorable climatic conditions and greater resistance to diseases and pests than anything now known. How far the wheat plant can go in these directions is not yet fully determined, but it is certain that other genera of grasses possess some characters that are superior to those of wheat. Is it possible to breed the desirable traits of these grasses into wheat by crossing, as is done when different kinds of wheat are crossed to get several desired traits into a single variety? The work is difficult and it might give little or no result, but the possibilities are alluring because they might revolutionize some agricultural practices.

A beginning has been made in crossing wheat with *Aegilops* (goatgrass), *Haynaldia* (boat grass), *Secale* (rye), and *Agropyron* (wheatgrass). The great diversity of forms obtained in various hybrids is indicated in figure 10.

Aegilops is an interesting genus represented by a variety of forms found growing wild in the countries bordering the Mediterranean. All of them produce heads that drop off at maturity or break into pieces. The majority of the forms have a low spreading habit. Some have shown resistance to wheat smut and others appear to be exceedingly hardy and vigorous. The fact that some forms of *Aegilops* are often found growing in close proximity to wheat and continue to reproduce abundantly without apparent damage from some of the common wheat diseases at least suggests the possibility that they may be exceptionally resistant.

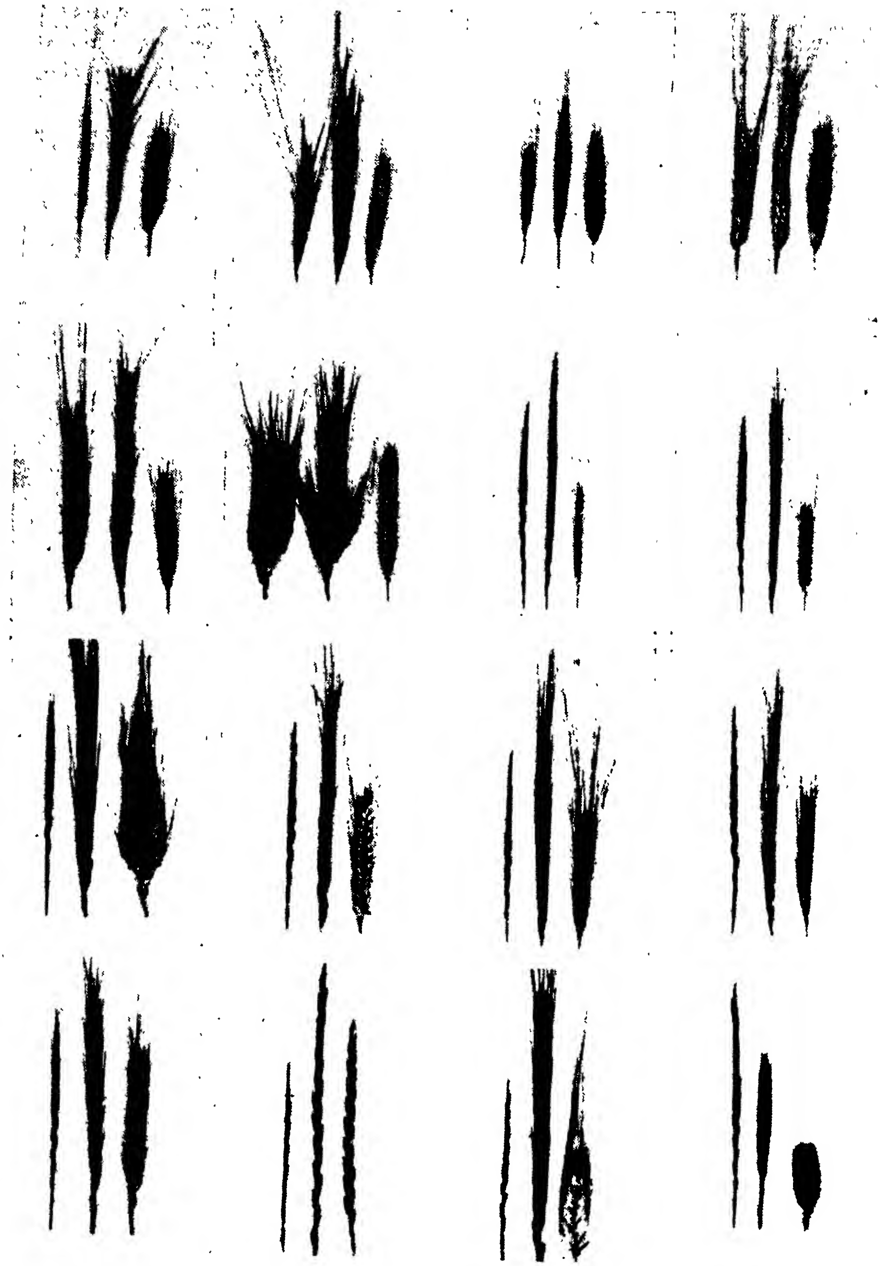


FIGURE 10.—Various wheat hybrids: The four panels in the top row and the first two from the left in the second row show wheat hybrids with boat grass; the remaining panels, hybrids of wheat with goatgrass. The wheat parent in each case is on the left and the other parent on the right. Note the vigor, size, shape, and great variation in the first-generation hybrid, shown between the parents.

When various forms of *Aegilops* are crossed with wheat species (fig. 11) the majority of the first-generation hybrid plants are self-sterile—that is, they cannot be fertilized by their own pollen. When these plants are again crossed with wheat, however, a small percentage of seed is produced. Further crossing with wheat brings an increase in fertility in the resulting progeny, and fertile forms of these final crosses may be selected that combine characters of the *Aegilops* and the wheat parents. It takes many years to do this work, since ordinarily only one generation is produced each year, though the use of the greenhouse may speed up the work somewhat.

Occasionally certain crosses of wheat with *Aegilops* produce first-generation hybrids that show a slight ability to be fertilized by their own pollen and will produce a few seeds. In succeeding generations no segregation into different types occurs but the fertility may increase. These hybrids that do not split up into different types are called amphidiploids. They combine the characters of the two parents and possess the full number of chromosomes of both together. They seem to be fixed, and the question is whether they are not really new genera of plants.

FIGURE 11.—Parents and a progeny of wheat × *Aegilops*: *A*, *Aegilops*; *B*, first-generation hybrid; *C*, bread wheat.

Another form of wild grass with which wheat and rye have been extensively crossed is *Haynaldia villosa*, a species of boat grass. It is an Old World plant that is apparently quite limited in its distribution and variety of forms. The only fertile hybrid produced is that from the cross with a wheat, *Triticum turgidum*. The heads of this hybrid are fragile like those of the *Haynaldia* parent. Further hybridizations of this fertile hybrid with wheat are yet to be accomplished.

Rye can be grown in regions where the winters are too severe for even winter wheats, and this characteristic has supplied the incentive for a good deal of work in hybridizing wheat and rye. Although the first-generation hybrids (fig. 12) are readily made, they are entirely sterile to their own pollen. Crossing of these hybrids with wheat, however, produces a variety of types some of which are fully fertile to their own pollen while others are sterile in varying degrees. The fully fertile forms usually resemble wheat. New wheatlike plants with greater winter hardiness than any wheat have been reported. Partly fertile amphidiploids with 56 chromosomes have also been produced from crosses between wheat and rye.

FIGURE 12.—Wheat × rye: *A*, Bread wheat; *B*, first-generation hybrid; *C*, rye.

Agropyron is represented by a large group of species widely distributed over the earth. Certain forms possess a resistance to diseases and drought and a tolerance of extremely low and extremely high temperature far greater than is found in our wheats or ryes. Practically all species of *Agropyron* are perennials. Should it ever be possible to produce a wheat with a combination of the superior qualities of *Agropyron*, it might revolutionize wheat growing, since many of the hazards would be eliminated and the annual crop could be estimated in advance with certainty not now possible.

It is too early to predict what the ultimate accomplishment will be in this field. However, most of the species of wheat have now been crossed with one or the other of three species of *Agropyron* (*intermedium*, *trichophorum*, and *elongatum*). The first-generation hybrids of a cross between common bread wheat and *A. elongatum* are reported as being extremely fertile and a number of forms have been produced that show high resistance to rusts and smuts.

The measure of success attained from such wide crosses will depend on the amount of hybrid material produced; the training, patience, and persistence of the investigator; and his ability to recognize what is valuable in a large mass of material, most of which is worthless. Figure 13 indicates the kind of detail analyzed in some of the recent experiments.

Work has also been done in crossing the different species of wheat with plants of other genera. The wheats are classified in three groups which differ in the number and character of their chromosomes. The

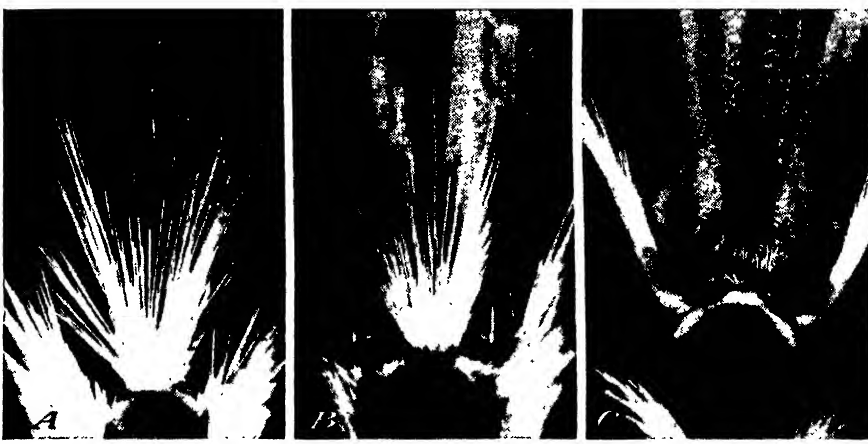


FIGURE 13.—Bristles at the base of spikelets showing the intermediate conditions of the first-generation hybrid (*B*) as compared to the two parents. (*A*) *Triticum dicoccoides* and (*C*) *Haynaldia villosa*.

einkorns, with 14 chromosomes, form the group that is considered lowest in the scale, or most primitive. The emmer group, with 28 chromosomes, comes next. Finally there is the vulgare or common wheat group with 42 chromosomes. This group is the most important economically since it includes the bread wheats that furnish so much of the world's food.

In the einkorn and emmer groups there are forms that, though they are of little value otherwise, have much greater resistance than the bread wheats to rust, smut, mildew, and drought. At one time it was believed that the difference in the chromosome make-up between these groups and bread wheats would hinder the transfer of desirable characters to the bread wheats. That was disproved, however, with the production of Hope wheat, which came from a cross between bread wheat and emmer. Hope combines the qualities of bread wheat with the rust resistance of emmer, and is valuable foundation material for future breeding work.

CROSSING SUGARCANE AND SORGHUM—A FEAT OF INTEREST TO THE SUGAR INDUSTRY

Only a very limited area in the United States is adapted to the growing of sugarcane, which is essentially a tropical plant. The sorghums, some of which are relatively high in sugar content, are adapted to a wider area. The possibility of producing an entirely new plant of economic value, one with more sugar than sorghum and more adaptability than sugarcane, has interested plant breeders for some time. One of the chief advantages of such a plant would be that sugar factories could be kept in operation over a longer period than is possible with the short sugarcane season.

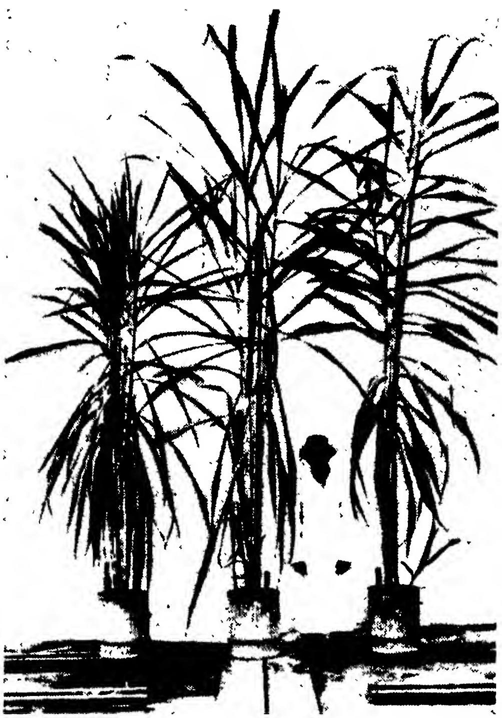


FIGURE 14.—Sugarcane×sorghum: Center, sugarcane parent, P. O. J. 2725, 12 months old; at either side, hybrids, 7 months old, obtained by crossing P. O. J. 2725 with *Sorghum durra*.

The sugarcane-sorghum hybrid has actually been made, but so far the possibilities have hardly begun to be explored. As in all crosses between genera, a large amount of material should be used if results are to be expected, and this means keeping several scientists working on the project over a considerable period of time.

The first hybrid was produced by a breeder in India who crossed sugarcane with a grain sorghum. The grain sorghums, of course, are not notable for sugar content, but the success achieved here showed that the cross could be made. It will be noted from the number of flower heads in the picture (fig. 15) that the work in India is apparently being done on a large enough scale to get results. Recently Department of Agriculture scientists, working on a very limited scale, have made not only this cross (fig. 14) but others between sugarcane and a variety of sorgo called Honey. The first-generation hybrids of the sugarcane-grain sorghum cross occasionally have great vigor, as indicated in the illustration by the size they have attained in 7 months as compared with the size of the year-old sugarcane parent.

As was to be expected, the cross produces many abnormal types, including albinos, which, of course, do not live past the seedling stage. Many of the progeny, however, resemble sugarcane and have a satisfactory sugar content. Inasmuch as sugarcane is reproduced vegetatively by cutting up the stem and planting the "seed cane," the work is somewhat simplified since the hybrids may be perpetuated with no danger of change.

FIGURE 15.—Preparing to pollinate sugarcane with sorghum heads in British-India. The heads are collected in the evening, trimmed, and preserved for use in pollinating the sugarcane flower early the following morning. (From Ind. Jour. of Agr. and Science.)

FIGURE 16.—A progeny segregating for normal and "lazy" corn plants. The lazy condition is due to the action of a single recessive gene which results in thinner cell walls and insufficient strengthening material in the stalk to hold it erect.

CROSSING CORN WITH TEOSINTE AND GAMA GRASS

Corn also has been used as a parent in wide crosses, with both annual and perennial teosinte. Teosinte is believed to be the closest relative of corn, and it is a useful forage plant, but none of the hybrids has shown that they might have practical value, though they have been of considerable interest to scientists. It is more difficult to hybridize gama grass with corn, and this cross has received less attention. A cross involving all three genera—corn, teosinte, and gama grass—has been reported.

Buried in the inheritance of the corn plant there are hundreds of striking and unusual characters. Most of them are recessive and do not show up except when special breeding methods are used. These characters have no economic value and some of them are seriously objectionable. Figure 16 illustrates the character known as "lazy," which is due to a single recessive factor. A plant that gets this factor from both parents is unable to stand on its feet after it is about half grown and spends the rest of its life lying down. Among other curious inherited traits in corn are the tunicate form, in which a husk covers each individual kernel; ramosa ears, which have many branches from base to tip; japonica, with white or yellow stripes running through the green leaf; silkless; tassel seed, usually with seed in the tassel and no pollen. Some of these traits have been of value to the scientist exploring the mode of inheritance in corn.

FIGURE 17.—Plant of the Mammoth type of tobacco which when photographed had 112 leaves. This type, which occurs occasionally as a mutation in several varieties, shows a remarkable response to length of day. At left are seen plants of the parent variety in bloom.

MAMMOTH TOBACCO PLANT LEADS TO IMPORTANT DISCOVERIES

It would be possible, if there were a demand, to produce tobacco with practically no nicotine. This has been done experimentally. Another striking, and in this case extremely useful, tobacco plant is the mammoth or giant form (fig. 17), originally a mutation. This form will not flower except when there are a certain number of hours of daylight and keeps on growing to a giant size as long as the days are not the right length for flowering. This happens during the long days of summer. When exposed to the short days of winter in a greenhouse, or even to relatively short summer days in very low lati-

tudes, it grows no larger than its parent variety and readily produces flowers. The striking nature of this phenomenon in tobacco led to scientific investigation and the discovery that the same principle has a widespread application among plants, so that under controlled conditions flowering and fruiting can in some cases be induced or postponed at will.

CHARACTERS OF VALUE OR POSSIBLE VALUE IN BARLEY AND OTHER CROP PLANTS

In barley, two sports, or mutations, have turned out to be economically important. At some time unknown—probably recently—a barley in Nepal, India, produced a sport, or mutant, that was hooded. This mutant, now known as Nepal, was the foundation for all the hooded barleys grown today in North America.

Barley usually has rough awns, which are troublesome in harvesting, and the smooth-awned character rarely occurs, but one such form was used as the basis for our modern smooth-awned varieties. Most queer barleys, however—dwarf and semisterile plants, for example—are weak and useless. A strain that produces only one stem to a plant has been found in California. This might be combined with other desirable features to make a useful nurse crop. Nurse crops that send up many stems often make so dense a shade that they kill the crop with which they are planted.

Brown and Green Cotton

As in the case of nicotineless tobacco, cotton that would be brown or green without any dye could be produced if there were a demand for it. Both brown and green fiber are found in upland cottons. The brown is yellowish in color, or almost cream; the green is bright and intense. The plants with the colored fiber usually breed true, which indicates that they are a stable combination or mutation.

The most probable explanation is that the color is due to certain factors that have existed in the germ plasm of the plant since it grew in a wild state. It may be noted that some varieties of cotton have green fuzz but white fiber.

Practically all sea-island and Egyptian cotton that has reached us by way of South America has some color in the lint, though it may be no more than a pale cream.

Rice Variety Protects Heads From Insects

In the rice variety Sathi (no. 132), which is quite extensively grown in the United Provinces of India, the flower head remains almost entirely enclosed by the leaf sheath. In most commercial varieties the flower head pushes fairly well up out of the leaf sheath. The arrangement in the Sathi variety protects the grain from injury by the insect known as the rice sapper, which sucks the milky juice from developing kernels. Sathi is thus of considerable economic importance, for in certain districts the rice sapper may destroy as much as half the crop if it consists of varieties that push the head up where it is exposed to insect attack.

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Flax That Threshes Itself

One of the unusual members of the flax family is self-threshing (fig. 18). In this variety—Crepitans, or dehiscent flax—the bolls open fully when they are ripe and the seed falls to the ground. If the plants are pulled and placed in a bag as soon as the earliest bolls mature, all of the seed can be saved and the plants do not have to be threshed. However, the yield is low. In tests at Bozeman, Mont., yields at the rate of 8 to 20 bushels an acre, about half those of the best seed flaxes, have been obtained with this curious variety. It is probably a primitive type and is still grown to a limited extent in certain localities in Germany, the Ukraine, and Spain.

FIGURE 18.—A bundle of dehiscent or self-threshing flax, in which the seeds shatter out as soon as ripe. This variety, Crepitans, is grown to a limited extent in Spain, Germany, and the Ukraine. Seed of the strain shown (C. I. 761) was obtained from Spain.

Desirable Characters of Naked and Dwarf Oats

Its many-flowered spikelets, hull-less kernels, and attractive appearance have made naked oats (fig. 19) subject to exploitation as a valuable new variety, although because of certain undesirable economic characters the naked oat has not become of commercial importance in the United States. At one time it was believed that the plant might have breeding value for getting the many-flowered character—which theoretically would also mean more grain to each plant—into a good hull oat. Genetic research showed that the many-flowered spikelet and the naked kernel are linked—that is, one cannot be inherited without the other. Thus in crosses any true-breeding progeny that has a hull also has a reduced number of flowers. So far it has not been possible to break this linkage in crossing hull with hull-less oats.

Dwarf oats might possibly be useful as a crop to sow with spring oats, wheat, or barley. After the latter had been harvested for grain, the dwarf oats would be left as a highly nutritious pasturage, especially for sheep. In this connection it is of interest to know that both recessive and dominant dwarfness have been reported. A recessive prolific dwarf is shown in figure 20.

FIGURE 19.—Panicle, spikelet, and kernels of naked or hull-less oats. Hull-less oats have not competed with ordinary oats largely because of low yield, susceptibility to disease, and weak straw. In recent years these disadvantages have been overcome to some extent through breeding.

FIGURE 20.—A dwarf oat obtained from an Aurora × Pringle Progress cross. This particular dwarf breeds as a recessive and produces an abundance of seed under conditions favorable to its growth. (Dwarfs in foreground, normals in background.)

A very stiff, rather short-strawed dwarf oat (fig. 21), sometimes referred to as the "Trelle dwarf" because Herman Trelle, of Wembly, Alberta, Canada, first observed it, is of much interest from a botanical standpoint, and because of its stiff, rigid stem, it might be useful for breeding oats with superior straw.

FIGURE 21.—Panicles and spikelets of the Trelle dwarf oat.

The occurrence of variations with multiple flowers in both common and red oats has been observed. A condition in which the kernel is not enclosed tightly within the hull occurs infrequently in certain varieties. Plants without chlorophyll, or green coloring matter, have been found. This condition, of course, is deadly or lethal to the plant, since without chlorophyll it cannot manufacture food.

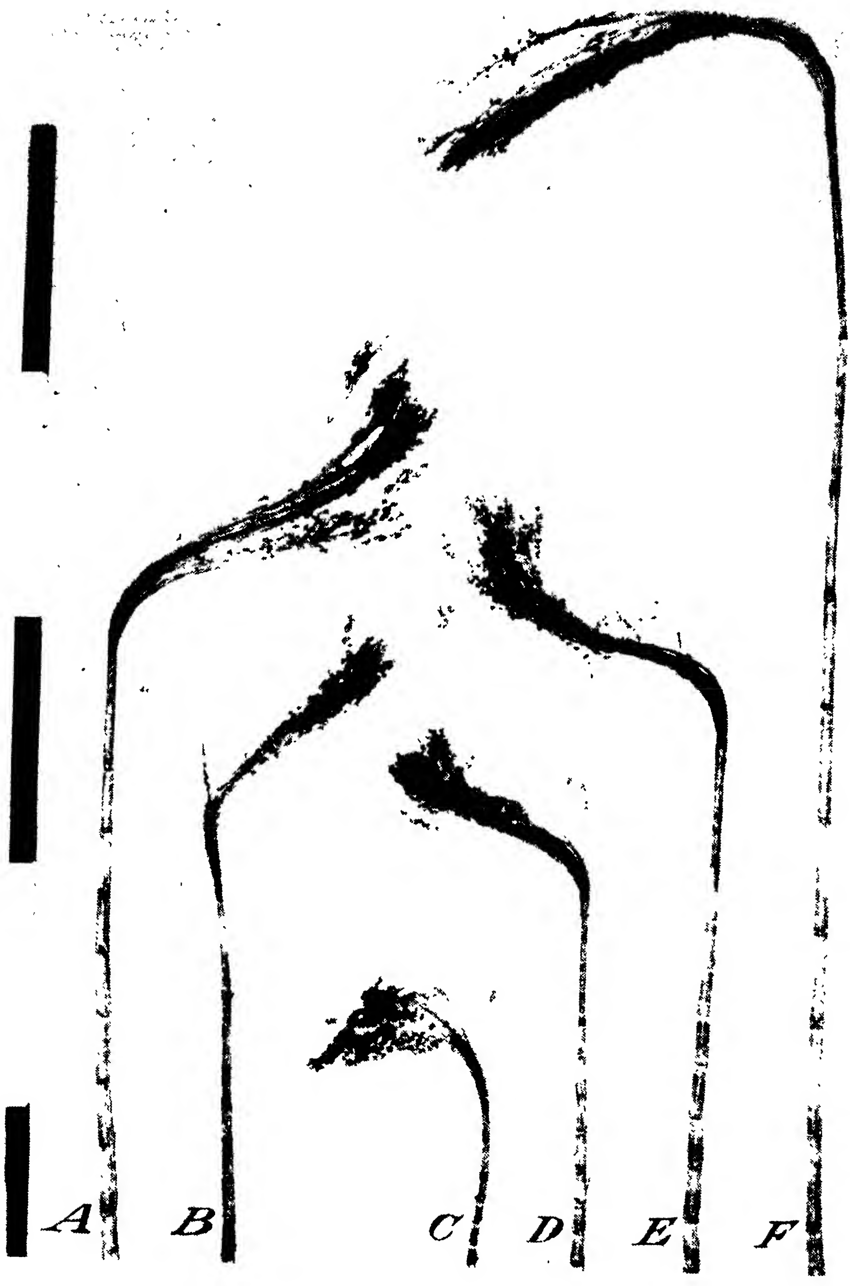


FIGURE 22.—Broomcorn stalks with the leaves removed: *A*, Evergreen Dwarf; *B*, Japanese Dwarf; *C*, Double Dwarf; *D* and *E*, parental types recovered in the second generation; *F*, tall (standard type) broomcorn.

Other deficiencies in green coloring matter, only partially lethal, such as yellow stripings of the leaves, sheaths, and gumes (part of the hull), occur more frequently. All plants completely lethal die soon after they emerge from the seed, and partial lethals usually are less vigorous than normal plants. These variations are of no economic value for breeding.

Dwarf Broomcorn for Whisk Brooms

There is a double dwarf broomcorn (fig. 22) that might be worth while for making toy brooms and whisk brooms except that the brush as well as the stalk is abnormally short. In crosses between Japanese Dwarf and Evergreen Dwarf broomcorn, one-sixteenth of the plants in the second hybrid generation turn out to be of the double-dwarf type. A double-dwarf kafir occasionally appears among plants of normal kafir through the mutation of a single factor in the germ plasm, but it is low in yield.

Improvement in Wheat

By J. Allen Clark, Senior Agronomist, Wheat Investigations, Division of Cereal Crops and Diseases, Bureau of Plant Industry

HOW was it discovered that the small hard seeds of the wheat plant are good food for men? One guess is as good as another. At any rate, the discovery was made long before recorded history. Archaeologists digging in Turkey, exploring the tombs of Egypt, turning up cooking pits and storage vessels in many other countries, have come upon carbonized grains of wheat; and some of these date as far back as 6,000 years. In very ancient times, then, man was already a wheat eater. It is not easy to see how breadmaking was first discovered, perhaps by some lucky accident noticed and utilized by a genius among primitive housewives.

The fact is that the physical and chemical properties of the gluten in wheat are such that it produces breadstuffs superior, on the whole, to those made from any other grains; and at the same time wheat is peculiarly suitable, in the proper combinations with other foods, for human nourishment. Thus its own intrinsic merits have made it the chief food of man, though rice shares that distinction in large areas of the world. Much of the energy for the work done by man has for generations been furnished by wheat. Civilization is in part a product of wheat, which could be grown, stored, and prepared in relatively large quantities by comparatively few men, thereby releasing human energy for pursuits other than constantly hunting a food supply.

It is not too much to say that the improvement of wheat, by genetic or other means, is important to man in proportion to the importance of the plant itself.

At the beginning of its recorded history, wheat was already a cultivated plant, and some of the species now known were distinguished and recognized. Thus in 300 B. C. Theophrastus (*100*),[1] a pupil of Plato, wrote in his Enquiry Into Plants "There are many kinds of wheat which take their names simply from the places where they are grown." Columella (*30*), writing shortly after the beginning of the Christian Era, in 55 A. D., mentioned several groups of plants, in-

[1] Italic numbers in parentheses refer to literature cited, p. 261.

cluding *Triticum*, the genus that includes the wheat varieties commonly used today. It is evident, then, that 2,000 years ago, wheat had been cultivated long enough for many of the plant's chief characters to be matters of common knowledge.

Undoubtedly, however, the major improvements in the plant were made, not by the cleverness of man, but by the slower processes of nature. Probably primitive farmers found the plant a rather superb product at the time they began cultivating it. It is possible that in very remote times the plant was cross-fertilized and that vigorous self-fertilized or inbred forms were developed by nature over a long period, during which the distinct self-fertilized species and varieties known today were finally set.

Many of these have been discovered and described by botanists in modern times, beginning with Linnaeus (C. von Linné) (*62*) in 1753. In his Species Plantarum, the grandfather of systematic botany described seven species of the genus *Triticum*. Of these, the chief are the common or bread wheats (*T. vulgare* Vill.), varieties of which were first extensively grown in northern Europe; the club wheats (*T. compactum* Host), varieties of which were grown in southern Europe, especially in Spain; and the durum wheats (*T. durum* Desf.), varieties of which were first cultivated in the Mediterranean countries, in southern and eastern Russia, and in Asia Minor.

Each of these three species—and others as well—has distinct characters and qualities that make it suitable for special uses. The club wheats are soft and are used for pastry; the durum wheats are hard and are used for macaroni; the common wheats are more or less intermediate and are used for bread.

Around the World With the Breeders of Wheat

NATURALLY the major food plant, wheat, is grown very extensively throughout the world. It occupies 300 million acres a year in 50 different countries. The most important wheat-producing countries in 1921–22 to 1925–26, as shown in the 1934 Yearbook of the Department of Agriculture, are listed in the tabulation that follows. It will be noted that the wheel horses in world wheat production, from the standpoint of acreage, are:

United States, 57½ million acres.
China (commonly thought of as a rice rather than a wheat country), 46 million acres.
Union of Soviet Socialist Republics, 43 million acres.
India (also commonly thought of as a rice country), 29½ million acres.
Canada, 22 million acres.
Argentina, 16 million acres.

France, Italy, and Spain together have a total of 35½ million acres in wheat, and Australia throws in 10¼ million. The United States and Canada combined account for more than 79½ million, or over one-fourth of the world's 300 million acres.

Principal wheat-growing countries

[Over 1,000,000 acres]

Country	5-year average acreage, 1921–22 to 1925–26	Country	5-year average acreage, 1921–22 to 1925–26
North America:		Europe—Con.	
United States	57, 557, 000	England	1, 746, 000
Canada	22, 083, 000	Czechoslovakia	1, 526, 000
Mexico	2, 098, 000	Portugual	1, 078, 000
		Greece	1, 075, 000
Total	81, 738, 000		
		Total	107, 427, 000
South America:			
Argentina	16, 159, 000	Asia:	
Chile	1, 446, 000	China	[1] 46, 000, 000
		India	29, 561, 000
Total	17, 605, 000	Turkey	7, 058, 000
		Japan	1, 197, 000
Europe:			
Union of Soviet Socialist Republics (including Asiatic)	43, 137, 000	Total	83, 816, 000
		Africa:	
France	13, 507, 000	Algeria	3, 406, 000
Italy	11, 575, 000	Morocco	2, 272, 000
Spain	10, 457, 000	Egypt	1, 462, 000
Rumania	7, 068, 000	Tunis	1, 400, 000
Yugoslavia	3, 953, 000		
Germany	3, 613, 000	Total	8, 540, 000
Hungary	3, 345, 000		
Poland	2, 957, 000	Australia (including New Zealand)	10, 234, 000
Bulgaria	2, 390, 000		

[1] 1933 acreage, computed from Crop Reporting in China, 1933. Published by the National Agricultural Research Bureau, Ministry of Industries, Nanking, China. This is the first formal crop estimate reported by China.

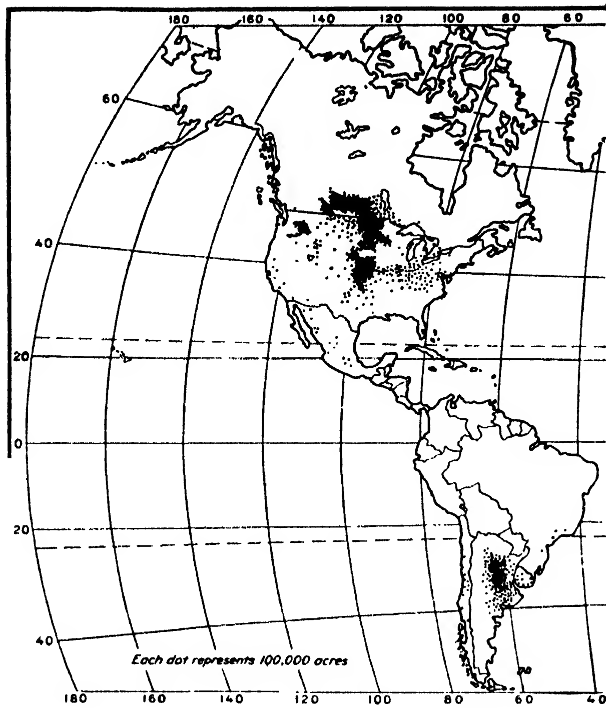
The distribution of the total wheat acreage of the world in 1931 is shown in figure 1.

For this study of superior germ plasm, an effort has been made to determine and summarize the wheat-improvement work accomplished in recent years. Questionnaires on the improvement in wheat were sent to administrators and plant breeders in leading agricultural institutions in each of the countries listed above. Schedules were sent by the Chief of the Office of Experiment Stations, United States Department of Agriculture, to the director of each of the 48 agricultural experiment stations in the United States.

THE STORY OF WHEAT IMPROVEMENT IN THE UNITED STATES

Wheat culture in the United States began along the Atlantic coast early in the seventeenth century and moved westward with the settlement of the country. One of the first things done by colonists and settlers was to start growing wheat. It was sown in the Jamestown Colony as early as 1611 and at Plymouth, Mass., soon after 1621. Naturally, too, one of the first things done was to import seed from abroad. A history of wheat improvement in the United States by Ball (*5*) shows that introductions from England were grown in New England as early as 1628 and in Maryland by 1634. Wheats from the Netherlands and Sweden came with colonists to New York, New Jersey, and Delaware from 1622 to 1638. Spanish wheats

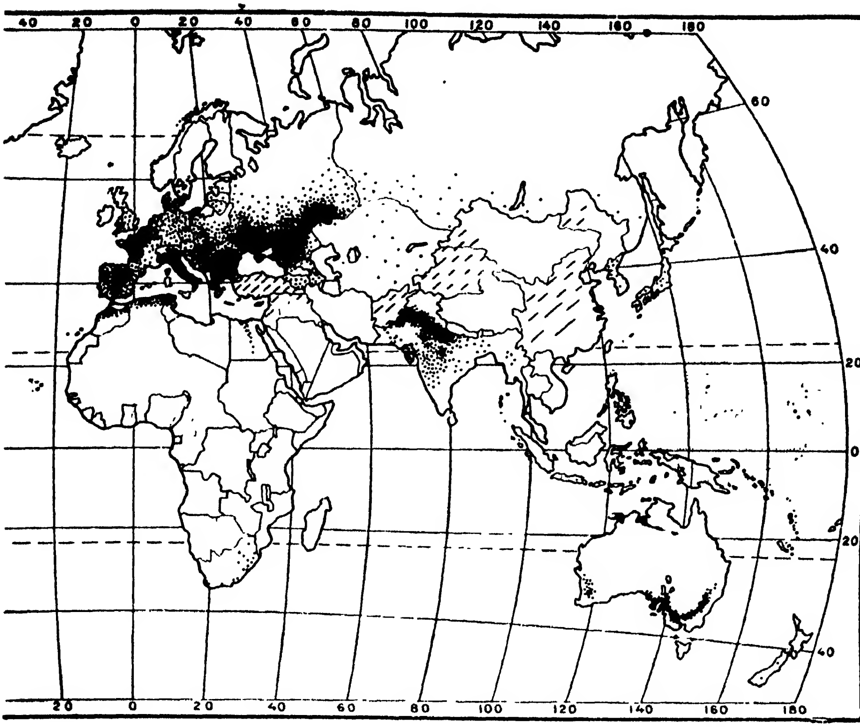
FIGURE 1.—Distribution of the total wheat acreage in the world in 1931.



were grown in California as early as 1770, coming from Mexico and the West Indies.

During the early period this introduction of new varieties from foreign countries was the only method of improvement, and many of the varieties introduced by early settlers became commercially important in later years. Most of these wheats have long since passed out of cultivation, replaced by other and better varieties, but some are still being grown after more than 100 years. Purplestraw, from a source still unknown, dates from 1822 and was grown on 150,000 acres in the Southeastern States in 1929. Mediterranean was sent to North America from some port on the Mediterranean in 1819 and soon became widely grown. Just 100 years later, in 1919, it occupied 2,770,000 acres in the war-time expansion area, and in 1929 it was still grown on 542,000 acres.

In California, Sonora, brought by the Spanish padres from the Magdalena missions in Mexico, is still being grown around Tulare Lake. This variety has been grown since 1825 by the Pima and Yuma Indians of Arizona. White Australian (now known as Pacific Bluestem), from the old White Lammas wheat of England, reached California from Australia in 1852. It was still grown on 364,000 acres in 1929. Hendry and Kelley (*50*) have found the remains of club wheat in adobe bricks of Spanish missions in California, built during the period from 1770 to 1800. Big Club from Chile is recorded as being grown in that State since 1866. White Winter, almost certainly an English wheat, was grown in the Willamette Valley of Oregon by 1855 and is still recommended for growing there.



Early in the nineteenth century another method of improvement developed when some of the leading farmers and seedsmen in the East began to make selections from the mixtures and natural hybrids in their fields. From their selections came many important wheats. Red May was selected by General Harmon in 1830 from the white-kerneled May, of English origin, grown in Virginia before the Revolutionary War. Fultz, an important soft red winter wheat, a descendant of a mixture or hybrid found in a field of Lancaster (Mediterranean), was selected by Abraham Fultz, a farmer of Mifflin, Pa., in 1862. It was still grown on nearly 1,500,000 acres in 1929.

A third method of improvement, the production of commercial varieties by hybridization, or by selection from the progeny of artificial crosses, dates from about 1870. For the most part this has been the work of specially trained men who have given their entire time to the work throughout a long period of years. Some of the earliest workers, however, were plant-breeding farmers. In 1886, S. M. Schindel, of Hagerstown, Md., crossed Fultz and Lancaster (Mediterranean) and named a selection Fulcaster. This proved to be a high-yielding variety of good quality and was widely grown. In 1929 it still occupied 1,400,000 acres.

A. N. Jones, a farmer who lived at Newark, Wayne County, N. Y., until about 1890, and later at Leroy, Genesee County, made a most remarkable record as a wheat breeder. He produced from hybrids at least 15 varieties that were grown commercially during the years between 1886 and 1906. Two of these, Jones Fife and Red Wave, are still grown. Jones was among the first to practice composite crossing, his Early Genesee Giant, distributed in 1893, being the product

of eight successive crosses. Other early private wheat breeders were Cyrus G. Pringle, of Charlotte, Vt., who produced the Champlain, Surprise, and Defiance varieties, and Elbert S. Carman, onetime editor of the Rural New Yorker, whose Rural New Yorker No. 6 was reported to have been produced in 1883 by crossing wheat and rye. The proof of the wheat-rye cross was later confirmed (*60*).

Following the establishment of the United States Department of Agriculture and especially the State agricultural experiment stations in 1887, much of the work in wheat improvement was gradually transferred from individuals to trained investigators in State and Federal institutions.

VARIETIES AND CLASSES OF WHEAT

Wheat varieties are generally designated by names established by publication and usage. Sometimes the same name is applied to different varieties, or one variety is grown under several different names, which results in confusion. Accurate identification of varieties, therefore, requires some knowledge of the appearance of the plant and kernel, and information regarding its origin and distribution is useful. Most of the commercial varieties grown in the United States have been classified by the writer and his associates and described in 1922 (*23*) and 1935 (*18*). Their histories, wherever possible, have been determined, synonymous names have been recorded, and their distribution has been mapped.

The gradual development of a system of commercial grades for wheat in the United States resulted in the Federal official grain standards. This system has played an important part in classifying wheat in commercial channels as to value and quality, especially as the country progressed from the growing of soft wheat only to the growing of three different classes of hard wheats. The latter formed the basis for the establishment of the modern milling, baking, and export industries.

Under the official grain standards of the United States, wheat has been divided into five commercial classes, which are grown in the following general areas:

(1) Hard red spring wheat—in the North Central States, where the winters are too severe for the production of winter wheat.

(2) Durum wheat—in the same general area, the leading States being North Dakota, South Dakota, and Minnesota.

(3) Hard red winter wheat—principally in the South Central States.

(4) Soft red winter wheat—in the Eastern States.

(5) White wheats—chiefly in the far Western States.

All the varieties of wheat commercially grown have been grouped under these commercial classes, and the acreages have been estimated at 5-year intervals for the years 1919 (*23*), 1924 (*25*), 1929 (*27*), and 1934.[2]

Superiority of germ plasm in wheat may be measured in three ways—by (1) the commercial acreage of varieties, which is an indication of their relative merit; (2) their relative performance as determined by carefully conducted experiments; and (3) successful use as parents in crosses that produce other superior varieties. All

[2] Unpublished data.

the commercially grown varieties may be considered to have some superior character or quality or they could not continue in cultivation.

The commercial varieties grown in the United States, arranged by classes and in the order of their estimated acreages in 1929, are shown in the appendix (p. 267).

Through a cooperative agreement between the Bureau of Plant Industry and the American Society of Agronomy, the 230 varieties of wheat described in 1922 were registered as standard varieties (*22*) in 1926. Since then, 48 additional varieties, originated through introduction, selection, or hybridization, have been registered as improved varieties (*16*). These improved varieties, registered on the basis of performance at State or Federal experiment stations, have superior germ plasm as determined from careful experiments over a period of years.

The varieties of wheat most widely grown usually are those best adapted to commercial use and growing conditions. However, new varieties are continually being developed by Federal, State, and private breeders. The United States Department of Agriculture and the State agricultural experiment stations test new varieties in comparison with the old and thus are in a position to recommend the best variety or varieties for each locality and State. The agricultural extension services then advise growers as to the best variety for any particular locality. New varieties having superior germ plasm should replace old inferior varieties as rapidly and completely as possible.

From the schedules on wheat improvement received from each of the wheat-producing States, the varieties of wheat now recommended for commercial growing in each of 40 States are given in the appendix (p. 267). These recommended varieties may be considered to have superior germ plasm as compared to that of other commercial varieties not on the list for any State.

VARIETIES DEVELOPED BY PRIVATE OR PUBLIC AGENCIES

The varieties of wheat recommended for commercial growing that were first distributed by private agencies, and those that have been developed and first distributed by State or Federal agricultural experiment stations, are listed chronologically in tables 2 and 3 in the appendix (pp. 269, 271).

The varieties shown in table 2 are those distributed since 1819 by private agencies, including early settlers, farmers, seedsmen, grain firms, and private breeders. Four of these varieties are of undetermined origin; 13 are the result of introduction (including varieties developed by selection and crossing from other countries); 13 are the product of selection; and 2 were developed by hybridization. The total estimated acreage of these 32 varieties in 1929 was 42,027,003 acres, and for 1934, 39,385,273 acres.

The varieties of wheat introduced or developed and first distributed by State and Federal agricultural experiment stations are shown in table 3 (p. 271). Eleven of these varieties are introductions from foreign countries, 59 are the result of selection, and 30 of breeding by hybridization. The total acreage of these 100 varieties listed as having originated from 1892 to 1934 was 12,954,141 acres in 1929, and for 1934, 17,077,034 acres.

The recommended varieties of wheat distributed by private agencies and by publicly supported experiment stations are the result of the three rather distinct methods of origin previously mentioned—introduction, selection, and hybridization. The important steps in the improvement of wheat in the United States are marked by the use of these three methods in turn.

Varieties Developed by Introduction

More striking than the growth of an oak from an acorn is the fact that the vast hard red spring wheat industry in the United States, with all the milling, baking, transportation, and trading dependent on it, developed from a few seeds saved from a single wheat plant. The origin of this plant shows how plant breeding cuts across and disregards national boundaries, to develop products useful to all men and all nations.

The variety that founded the hard spring wheat industry came originally from Galicia, in Poland. From Galicia it went to Germany. From Germany it went to Scotland. From Scotland it went to Canada. From Canada it came to the United States.

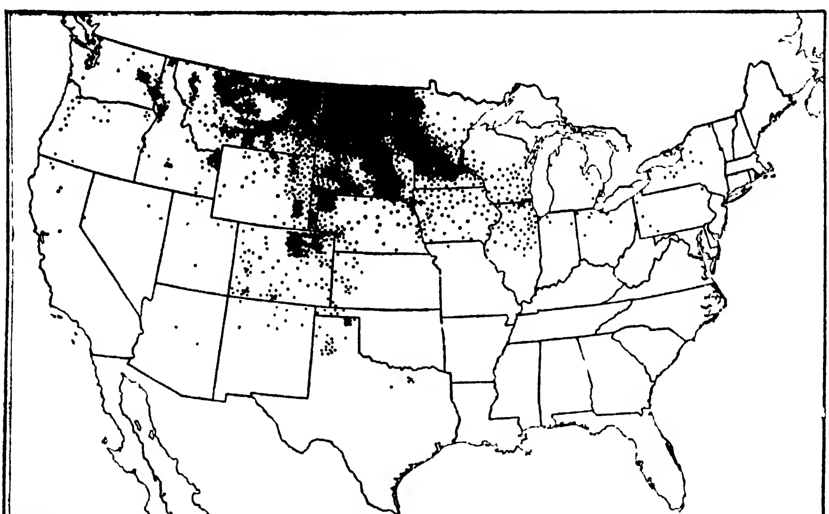


FIGURE 2.—Distribution of Marquis wheat in 1929; each dot represents 1,000 acres; estimated area, 11,786,590 acres.

It was David Fife, of Otonabee, Ontario, Canada, who first obtained a small sample of the wheat from a friend in Glasgow, Scotland. He sowed it in the spring, but it proved to be a winter wheat. A single plant of spring wheat developed out of the lot, however, and this was saved and increased. From this descended the wheat that became known throughout Canada as Red Fife. The cultivation of Red Fife wheat in the United States dates from 1860, when J. W. Clark, a Wisconsin farmer, had an excellent crop. The really

efficient use of hard red spring wheat, however, had to await the invention of the roller mill and the purifier, which could handle the grain effectively.

This Red Fife, in turn, became one of the parents of the world-famous Marquis wheat, also developed in Canada by C. E. Saunders. Marquis was a cross between Red Fife and Hard Red Calcutta, and it was introduced into the United States in 1912 by commercial seed and grain firms. Later, after careful testing, it was also introduced by State and Federal workers at experiment stations in several States, and it soon became the leading hard red spring wheat in the United States. In 1929 there were still 11¾ million acres sown to Marquis, as shown in figure 2.

MORE *striking than the growth of an oak from an acorn is the fact that the vast hard red spring wheat industry in the United States, with all the milling, baking, transportation, and trading dependent on it, developed from a few seeds saved from a single wheat plant. The origin of this plant shows how plant breeding cuts across and disregards national boundaries, to develop products useful to all men and all nations. The variety that founded the hard spring wheat industry came originally from Galicia, in Poland. From Galicia it went to Germany. From Germany it went to Scotland. From Scotland it went to Canada. From Canada it came to the United States. It was David Fife, of Otonabee, Ontario, who saved a single plant of spring wheat out of a lot of winter wheat obtained from a friend in Glasgow. From this single plant came the variety known as "Red Fife," which in turn was a parent of the world-famous Marquis, developed by C. E. Saunders. The development of Marquis has stood out for years as the greatest achievement in wheat-breeding history. As a parent in later crosses, it has passed on superior characters to Ceres, Hope, Marquillo, Reliance, Thatcher, Sturgeon, Comet, and in Canada to Reward, Canus, Apex, and Renown.*

The advantages of Marquis when it was first distributed were early maturity, enabling it to escape rust; high yields; and the excellent quality of the grain for milling and bread making. It is now considered a midseason variety in comparison with the early varieties more recently bred. It is also susceptible to stem rust, in comparison with the resistant and near-immune varieties now known, and it yields less now than several of the newer improved varieties. For 20 years, however, it remained the king of wheats, and a standard for comparing the performance of new varieties, both in the field and in the laboratory.

Of all wheat varieties, it may most be truly said to have superior germ plasm, since it has had the most universal approval of any variety by farmers, the grain trade, and the milling and bread-making industries. Its record has not been confined to direct production. It also has been successfully used as a parent in crosses, and such varieties as Ceres, Hope, Reward, Marquillo, Reliance, Thatcher, Sturgeon, Comet, and Canus, hard red spring wheats, and Tenmarq, hard red winter, have Marquis as a parent.

FIGURE 3.—Marquis wheat; spikes and glumes natural size; kernels × 3.

The first introductions of hard red winter wheats, now grown in a vast area in the Southwest, were made by a small group of Mennonites who emigrated from southern Russia and came to the middle Great Plains in the United States. In 1873 they settled in central Kansas, principally in the vicinity of Newton and Halstead. With them they brought seed of Turkey wheat, and they found it to be well adapted to the new country. The wheat attracted only local attention, however, until Carleton (fig. 4), one of the pioneers in plant improvement, discovered it and recognized its resistance to drought and its good yields under adverse conditions. Carleton was so impressed with the possibilities of the growing of hard red winter wheat in this area that he went to Russia in 1900 for the special purpose of getting additional strains. He brought back and distributed Turkey, Kharkof, Crimean, Beloglina, and other named sorts.

Thus, though private introductions started the ball rolling, the work of Carleton of the United States Department of Agriculture, and his later introductions, played an important part in establishing the hard red winter wheat industry. For many years, Turkey wheat has been the most widely grown variety in the United States. Its distribution in 1929 is shown in figure 5. Turkey wheat, therefore, has superior germ plasm suitable for wide adaptation. Turkey and Kharkof are the standard hard red winter wheats in comparison with which the improvement of new varieties is judged.

Durum wheat had also been produced at various times by farmers but had failed to become important commercially. Again it was Russian settlers in North Dakota who introduced Arnautka and started the commercial culture of durum wheat in the State about 1898. Two years later, in 1900, Carleton introduced quantities of Kubanka and other varieties from southern Russia, and also purchased seed of Arnautka in North Dakota. This seed was grown under contract in South Dakota in 1901, and the following year 200 bushels of several varieties were distributed to farmers. The distribution of Kubanka was continued by the Department up to 1909. After 35 years of culture, Kubanka is still recognized as the most widely adapted durum wheat and is the standard durum variety for judging the improvement of new durum varieties developed by selection or hybridization. The distribution of Kubanka in 1929 is shown in figure 6.

FIGURE 4.—M. A. Carleton, cerealist, United States Department of Agriculture, 1894 to 1918, Washington, D. C. Introducer of varieties of hard red winter (Kharkof) and durum (Kubanka) wheats. Deceased April 24, 1925

Among the soft red winter varieties, Mediterranean, the introduction of which has already been discussed, has been a standard for judging improvement in this class of wheat for over 100 years. Its distribution is shown in figure 7.

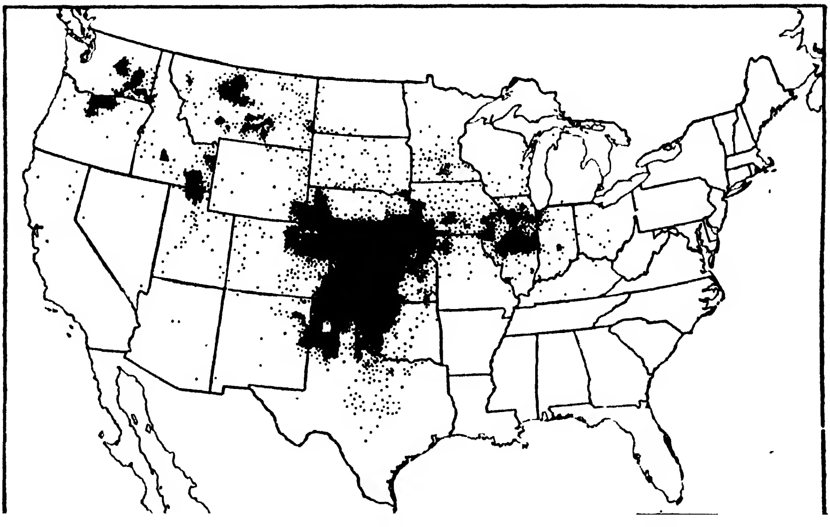


FIGURE 5.—Distribution of Turkey wheat in 1929; estimated area, 15,925,677 acres.

White wheat improvement is judged upon the basis of Baart, also an introduction by the United States Department of Agriculture, obtained from Australia in 1900. The commercial production of the variety in this country is the result of this introduction. Seed was first increased and distributed for commercial growing by the Arizona Agricultural Experiment Station in 1910. The variety was well established in Arizona by 1914 and later spread to Oregon, Idaho, Washington, and California. The distribution of Baart wheat in 1929 is shown in figure 8. Baart wheat has superior germ plasm for drought resistance, as it is recognized as the most drought resistant variety grown in the United States.

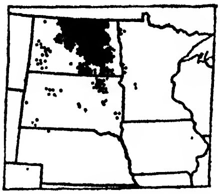


FIGURE 6.—Distribution of Kubanka wheat in 1929; estimated area, 724,864 acres.

Federation white wheat, introduced by the United States Department of Agriculture from Australia in 1914, is fast becoming the leading white wheat in the United States. Its superiority consists in high yields under both dry-land and irrigation farming. It is a vigorous stooling variety, that is, it sends out many shoots around the base of the plant, it has short, stiff straw, and although a spring wheat, it is successfully grown from fall seeding in mild climates. It was bred by the late William Farrer, another pioneer in plant breeding on the opposite side of the world, in New South Wales, Australia. Federation came from a cross between Purplestraw and Yandilla. The latter is from a cross between Red Fife (Improved) and Etewah, an Indian variety. Federation is the greatest of Farrer's many triumphs in wheat breeding (fig. 32).

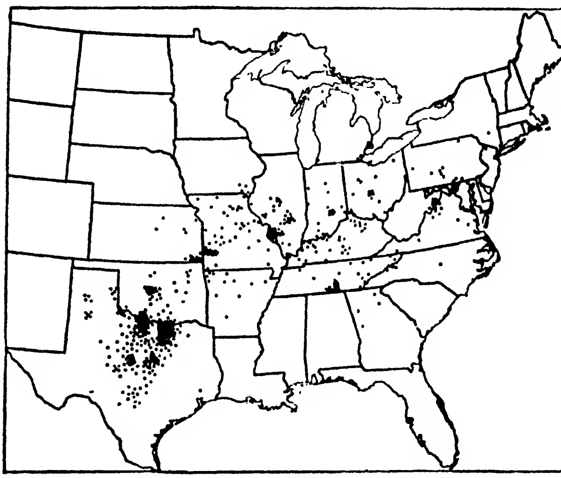


FIGURE 7.—Distribution of Mediterranean wheat in 1929, estimated area, 542,793 acres.

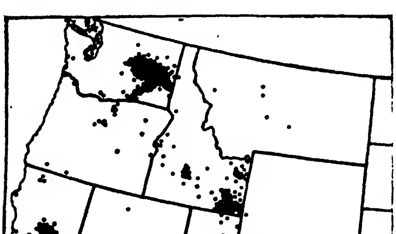


FIGURE 8.—Distribution of Baart wheat in 1929; estimated area, 766,547 acres.

In the United States, this variety first showed promise in experiments at the Sherman County Branch Station, Moro, Oreg. Here the seed was increased by D. E. Stephens and it was first distributed by the station in the spring of 1920. The distribution of Federation wheat in 1929 is shown in figure 9.

Other men who have played important roles in the introduction of wheat in the United States, in addition to M. A. Carleton of the United States Department of Agriculture, are H. L. Bolley of the North Dakota Agricultural Experiment Station and N. E. Hansen of the South Dakota Station. Introductions from Russia by Bolley were Pentad (D-5) and Monad (D-1), rust-resistant durum wheats, and the material from which Kota was later selected. Pentad, red durum, distributed in 1911, was the first rust-resistant variety of wheat to become widely grown. Its acreage increased rapidly, especially when used in late seedings. It has superior germ plasm for rust resistance, and its agricultural worth has been far-reaching, although the quality of its grain is inferior. It cannot be used for flour or semolina for the manufacture of macaroni, but its production developed a profitable feed-grain business.

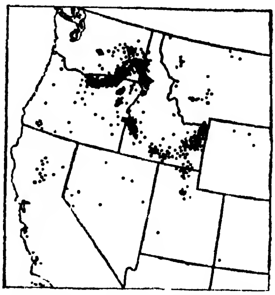


FIGURE 9.—Distribution of Federation wheat in 1929; estimated area, 752,867 acres.

The United States Department of Agriculture has obtained over 8,000 foreign introductions of wheat and now has viable seed of nearly 5,000 of these. This collection includes the leading varieties from more than 50 different countries. While introduction is still being used as a method of wheat improvement in the United States, it reached its height at the close of the nineteenth century. This period was marked by the appearance of the pure-line theory of Johannsen and the rediscovery of Mendel's law of heredity by De-Vries, Correns, Tschermak, and Spillman. The stage was set for the more scientific methods of improvement, selection, and hybridization, in the twentieth century.

VARIETIES DEVELOPED BY SELECTION

The pure-line or "single line" theory of Johannsen of Copenhagen stimulated important work for the improvement of wheat by selection. Johannsen first defined a pure line in 1901. It is the progeny of a single self-fertilized individual of homozygous factorial composition.[3] Wheat is a self-fertilized crop and the possibilities for improvement of varieties by selection of a single head or plant were quickly recognized. Many selections were made and compared. It was soon found, as Johannsen (*54, p. 103*) pointed out in 1906, that not all of the so-called pure-line selections were pure or homozygous for all characters. Percival (*79, p. 77*) has pointed out that the term "single line" satisfies Johannsen's definition and avoids unjustifiable implications which the word "pure" conveys and has suggested that this term be used in the future.

The breeding of wheat by "single line selection" in the United States resulted in the development of several important varieties.

[3] See the Glossary of Genetic Terms, p. 153.

Outstanding among these is Kanred (Kansas Red), selected by H. F. Roberts (fig. 10) of the Kansas Agricultural Experiment Station from Crimean (C. I. No. 1435), introduced by Carleton from Russia. From hundreds of selections, Kanred was developed as a strain superior to the parent and other selections and was distributed for commercial growing in 1917. It was grown on nearly 5 million acres by 1925. The distribution of Kanred wheat in 1929 is shown in figure 11.

At the Ohio Agricultural Experiment Station, plant selections among the commercial varieties made by C. G. Williams were most successful. He developed the Trumbull, Gladden, Portage, Fulhio, and Nabob varieties, which are now the principal varieties of wheat grown in that State.


FIGURE 10.—H. F. Roberts, botany department, Kansas Agricultural Experiment Station, 1901 to 1919, pioneer in wheat breeding by selection. He selected 554 wheat heads in 1906, 1 of which resulted in Kanred. Manitoba Agricultural College, Winnipeg, Manitoba, Canada, 1920- —.

Trumbull is a selection from Fultz. Its superior characters are winter hardiness and good yield under Ohio conditions. It is immune from loose smut and resistant to stinking smut (bunt) and scab. It has stiff straw and the grain is of good appearance and quality. Since it was first distributed in 1916, the increase in the acreage of Trumbull in Ohio has been very rapid. It rose from 1,900 acres in 1919 to 593,427 acres in 1924, and to 902,699 acres in 1929, as shown in figure 12. In the latter year it was grown also in seven neighboring States.

In Minnesota early plant-selection work by the centgener method developed by W. M. Hays (later Assistant Secretary of Agriculture) resulted in the development of the Haynes Bluestem (Minn. No. 169) and Glyndon Fife (Minn. No. 163) wheats, which became important in that State. This pre-Mendelian centgener method of breeding, not now used, involved continuous selection in a plot of 100 plants in which each kernel was planted a certain distance from the next kernel. Later selection work at the Minnesota Agricultural Experiment Station resulted in Mindum (Minnesota durum). This selection of durum wheat has become very popular in recent years. Next to Marquis, it has had the most nearly unanimous acceptance by the grain trade of any new varieties developed by the experiment stations. The superior characters of Mindum are its high yield, heavy test weight per bushel, and the bright amber color of the grain, which is reflected in the desired color and quality of semolina and macaroni manufactured from it. The distribution of Mindum is shown in figure 13.

In Michigan, the selection of Red Rock wheat by F. A. Spragg is outstanding. Its superior characters are stiff straw, high yield, and the good quality of the grain. Its distribution is shown in figure 14.

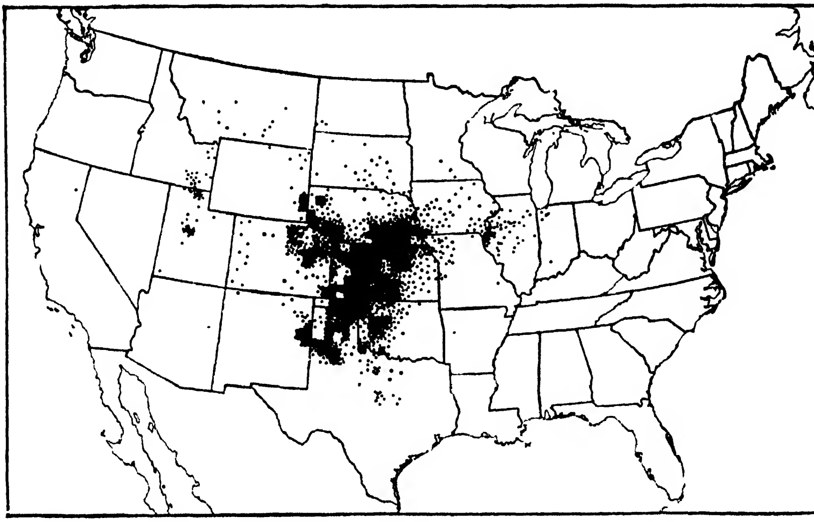


FIGURE 11.—Distribution of Kanred wheat in 1929; estimated area, 3,490,184 acres

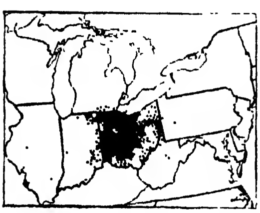


FIGURE 12.—Distribution of Trumbull wheat in 1929; estimated area, 902,699 acres

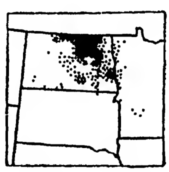


FIGURE 13.—Distribution of Mindum wheat in 1934; estimated area, 322,151 acres.

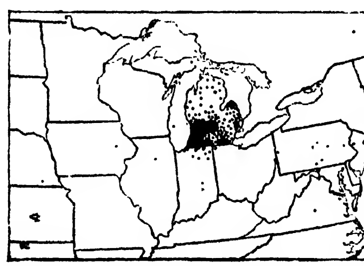


FIGURE 14.—Distribution of Red Rock wheat in 1929; estimated area, 261,246 acres.

At the Pennsylvania Agricultural Experiment Station, the selection of Nittany (Penn. No. 44) by C. F. Noll, from the Fulcaster variety, is a marked improvement. The superior characters of Nittany over Fulcaster are greater vigor, stronger straw, and higher yields. The distribution of Nittany wheat is shown in figure 15.

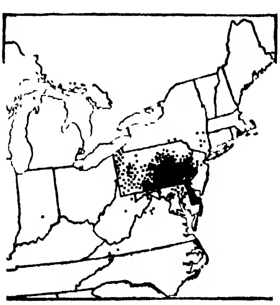


FIGURE 15.—Distribution of Nittany wheat in 1929; estimated area, 398,312 acres.

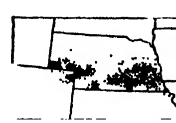


FIGURE 16.—Distribution of Nebraska No. 60 wheat in 1929; estimated area, 345,163 acres.

The selection of Turkey wheat in Nebraska by T. A. Kiesselbach resulted in the production of Nebraska No. 60 and Cheyenne, which was also an important improvement. The distribution of Nebraska No. 60 is shown in figure 16.

In Iowa, selection within introduced and commercial varieties is still the principal method of breeding and has resulted in the development of several important varieties—for example, Iobred, Ioturk, and Iowin by L. C. Burnett. In New York, the selection and development by H. H. Love of Forward, a soft red winter wheat, and Honor, a white wheat, are marked improvements in both these classes. Love also has organized the recent wheat-breeding work in China.

In addition to the improvement of wheat made by selection at agricultural experiment stations, several private breeders have made outstanding contributions. Principal among these are the contributions of Earl G. Clark, a farmer plant breeder, of Sedgwick, Kans., who originated Blackhull from a selection in a field of Turkey made in 1912. Clark distributed his Blackhull wheat in 1917 and its increase was phenomenal. The distribution of Blackhull wheat in 1929 is shown in figure 17.

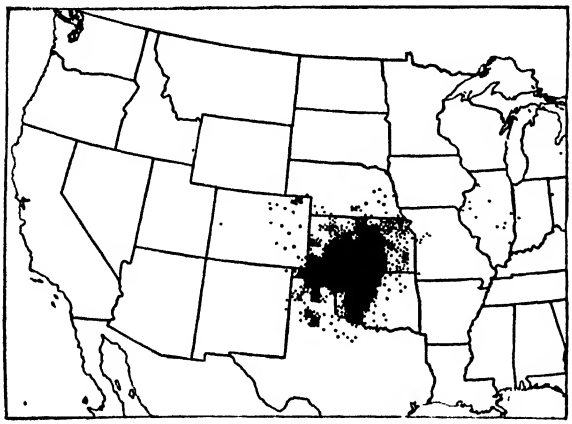


FIGURE 17.—Distribution of Blackhull wheat in 1929; estimated area, 5,959,067 acres.

This variety ranked second among the hard red winter wheat varieties grown that year. The superior characters of Blackhull are strong straw, drought resistance, and high yield.

VARIETIES DEVELOPED BY HYBRIDIZATION

Fulcaster, already discussed as being developed through hybridization by a private breeder, S. M. Schindel, another farmer breeder, is a most outstanding variety. It has been widely grown for many years. Its distribution in 1929 is shown in figure 18.

The production of commercial varieties through hybridization by trained men at State and Federal agricultural experiment stations in the United States dates from about 1890. A. E. Blount at the Colorado Agricultural Experiment Station was among the first to breed varieties by hybridization. He produced more than a dozen named varieties. Living in a mining State, he adopted the quaint habit of naming his varieties for native rocks and minerals, such as Amethyst, Feldspar, Granite, Gypsum, etc. Several of his wheats were sent to Farrer of New South Wales, and these entered into the parentage of some of Farrer's best wheats. Gypsum is an ancestor of Bobs and Bunyip, and Hornblende also entered into Bunyip. As Bunyip later came from Australia to the United States, where it became widely grown, the work of Blount was an important contribution.

While he was engaged in pioneer wheat-breeding at the Washington Agricultural Experiment Station, the late W. J. Spillman (fig. 19)—who started the Bureau of Agricultural Economics in the United States Department of Agriculture—did work that resulted in the development of four commercial club wheats—Hybrid 128, Hybrid 123, Hybrid 143, and Hybrid 63. The first of these, Hybrid 128, until recently was the leading variety of club wheat grown in the United States. Its distribution is shown in figure 20. In the history of genetics the name of Spillman should be placed with those of DeVries, Correns, and Tschermak—who rediscovered Mendel's laws of heredity—for his paper on Quantitative Studies on the Transmission of Parental Characters to Hybrid Offspring, presented in 1901.

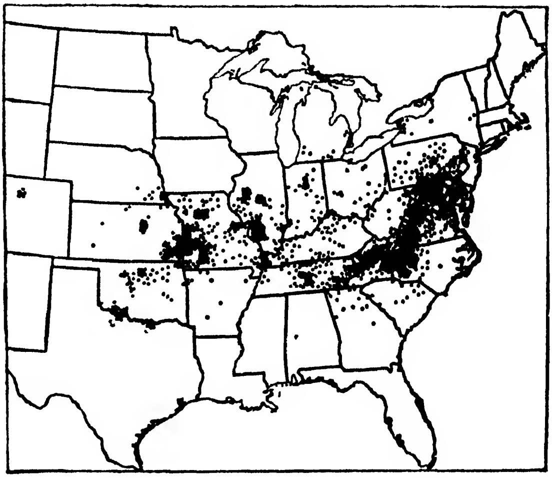


FIGURE 18.—Distribution of Fulcaster wheat in 1929; estimated area, 1,400,057 acres.

The development of Ceres, from the Kota × Marquis cross, by L. R. Waldron (fig. 21) of the North Dakota Agricultural Experiment Station, is one of the most successful examples of wheat improvement through hybridization in the United States. The cross was made in 1918 and Ceres was distributed for commercial growing in 1926. By 1932 it was estimated that 3 million acres were grown and in 1933 probably 5 million acres in the United States and Canada. Of this acreage, about 3 million acres were in North Dakota, 1 million in Minnesota, South Dakota, and Montana, and 1 million in Canada. The distribution of Ceres wheat for 1934 is shown in figure 23.

FIGURE 19.—W. J. Spillman, pioneer wheat breeder, Washington Agricultural Experiment Station, 1894–1901, a codiscoverer of Mendel's laws of heredity. Deceased July 11, 1931.

The superior characters of Ceres are resistance to stem rust and drought, high yields, and good quality. Its production has also been stimulated because it is less injured by grasshoppers than other varie-

ties, for reasons that are not fully understood. However, like all wheats, it has its inferior characters. *It is susceptible to bunt and loose smut, and the grain is long and dull. This is objectionable in* Montana, because both spring and winter wheats are grown in this State, and Ceres is often mixed and graded with hard red winter wheat. A field of Ceres wheat is shown in figure 22.

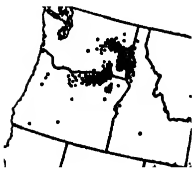


FIGURE 20.—Distribution of Hybrid 128 wheat in 1929; estimated area, 356,910 acres.

At the Minnesota Station, H. K. Hayes (fig. 27) and his associates, both Federal and State, have had marked success in wheat breeding by hybridization. Minturki, developed from a Turkey × Odessa cross, distributed in 1917, has become an important commercial variety, as shown in figure 24. In addition, Minhardi is one of the most winter-hardy varieties of wheat grown in the United States. It has superior germ plasm for hardiness and has been successfully used as a parent in further breeding for winter hardiness. Marquillo, developed from Marquis × Iumillo (durum), was the first hard red spring wheat commercially grown in which the rust resistance of the durum parent was transferred to a common hard red spring wheat.

The more recent production, Thatcher, distributed in 1934, and developed in cooperative experiments from the double cross, Marquis-Iumillo × Kanred-Marquis, is one of the most promising new varieties. It is resistant to stem rust and gives promise of being a widely adapted, high-quality wheat. Spikes and kernels of Thatcher wheat are shown in figure 25.

FIGURE 21.—L. R. Waldron, plant breeder, North Dakota Agricultural Experiment Station, Fargo, N. Dak., 1916—, breeder of Ceres and Komar wheats. He was made a fellow of the Linnean Society of London in 1933.

In the State of Washington, E. F. Gaines (fig. 29) has had marked success in the breeding of wheats for resistance to bunt or stinking smut. He produced the Ridit variety now widely grown, as shown in figure 26. Ridit has superior germ plasm for bunt resistance and has been used as a bunt-resistant parent in hybridization by other breeders. In addition, Gaines has produced such outstanding varieties as Triplet and Albit. The latter is now the leading club wheat grown in the United States.

At the Kansas Agricultural Experiment Station, J. H. Parker has produced the Tenmarq and Quivira varieties through hybridization. Although not as yet widely grown, Tenmarq promises to be commercially successful and may mark important improvements in the quality of hard red winter wheat.

FIGURE 22.—Field of Ceres wheat, Wild Rice, N. Dak., 1935.

E. S. McFadden of the United States Department of Agriculture, working in South Dakota, must be included among the leading wheat breeders of the United States for his production of the Hope and H–44 wheats, from crossing Marquis wheat with Yaroslav emmer. The Hope and H–44 wheats are nearly immune from black stem rust and are resistant to leaf rust, bunt, and loose smut. They have superior germ plasm for these characters and have been successfully and extensively used in further breeding for the control of stem rust and other diseases.

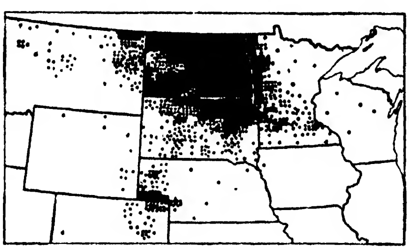


FIGURE 23.—Distribution of Ceres wheat in 1934; estimated area, 4,453,487 acres.

The wheat-breeding stations, early and present wheat breeders, commercial varieties, promising new strains, and the present work are summarized in the appendix for the different States and the Canadian Provinces. The locations of the wheat-breeding stations throughout the world are shown on the map (fig. 28), and the stations are listed in the appendix (p. 277). These lists constitute a directory of world wheat breeding. The numbers in parentheses preceding the stations correspond to their location on the map. The names of principal institutions and workers were compiled from different sources available in the Library of the United States Department of Agriculture. This list of workers is not intended to be a complete list; many other names could be included. The names of those who

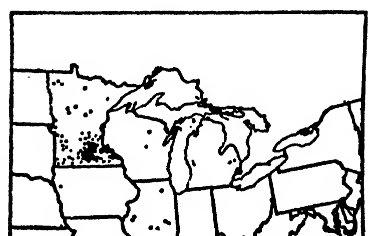


FIGURE 24.—Distribution of Minturki wheat in 1929; estimated area, 89,028 acres.

have furnished reports for this survey are marked with an asterisk. It is regretted that the limits of this article do not permit publication of all the information reported. However, response to the questionnaires is appreciated and here gratefully acknowledged.

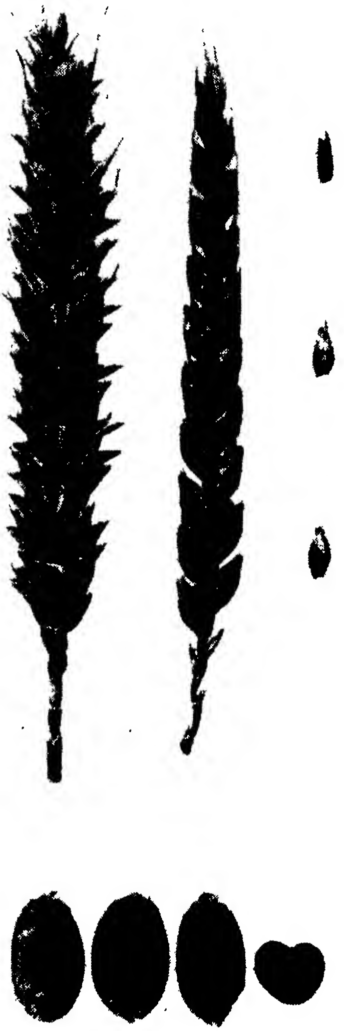


FIGURE 25.—Spikes and kernels of Thatcher wheat, developed in cooperative experiments at the Minnesota Agricultural Experiment Station.

The wheat investigations project in the United States Department of Agriculture, with S. C. Salmon in charge, is organized for cooperative wheat-improvement work with the State agricultural experiment stations. This cooperative work is largely on a regional basis, three regional programs having been organized with coordinators.

The hard spring wheat regional program, for the improvement of both hard red spring and durum varieties, with the writer in charge, was organized in 1928 and has included work at 24 stations, principally in the States of Minnesota, North Dakota, South Dakota, and Montana. Four conferences have been held at which talks or papers relating to the work were given, the experimental results were reviewed, and new work planned by the cooperating Federal and State workers.

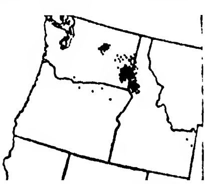


FIGURE 26.—Distribution of Ridit wheat in 1929; estimated area, 166,411 acres.

The hard red winter wheat program was organized in 1930, with K. S. Quisenberry in charge, and has included work at 25 stations, principally in Nebraska, Kansas, Colorado, Oklahoma, and Texas. Three onferences have been held.

In the western region a cooperative regional program was organized in 1930, with B. B. Bayles in charge, perincipally for the improvement

of white wheats. Two conferences have been held by the cooperating Federal and State workers in this region, which includes 19 stations where experimental work is carried on, principally in the States of Washington, Oregon, Idaho, Utah, Arizona, and California.

Mimeographed reports have been distributed containing the proceedings of the conferences and also annual summaries of the experimental work. In addition to these cooperative regional programs, coordinated from Washington, D. C., the Department has numerous men who have headquarters at Federal or State stations or substations throughout the States, where both practical breeding and genetic research work with wheat are conducted.

FIGURE 27.—H. K. Hayes, chief of the division of agronomy and plant genetics, University of Minnesota, 1915- —, University Farm, St. Paul, Minn.; breeder of Minturki and Thatcher wheats; president of the American Society of Agronomy, 1935.

The Work of Wheat Breeders in Foreign Countries

NORTH AMERICA

CANADA produces mostly hard red spring wheat. The wheat breeding is carried on by the Dominion Department of Agriculture at its Central Experimental Farm at Ottawa; at the Dominion Rust Research Laboratory, Agricultural College, Winnipeg, Manitoba; and at some of the Dominion experimental farms throughout the Provinces, such as at Brandon, Manitoba. Other wheat-breeding work is being done by the Provinces at the universities and agricultural colleges, but most intensively at those in the Prairie Provinces, at Saskatoon, Saskatchewan, and Edmonton, Alberta. The National Research Council of Canada organized the leading Canadian workers in the fields of agronomy and pathology into an Associate Committee on Field Crop Diseases and made provisions whereby the members meet annually to review their work and plan a "cooperative method of attack" on future breeding work. This committee now carries on under the joint auspices of the National Research Council and the Dominion Department of Agriculture.

The early wheat breeding in Canada was done largely at Ottawa, the Canadian capital in Ontario. William Saunders, the first director, introduced and distributed the Ladoga variety from Russia in 1888 and also distributed Red Fife, the latter forming the start of production of high-quality hard red spring wheat, throughout Canada. To his son, Charles E. Saunders (fig. 30), Dominion cerealist from

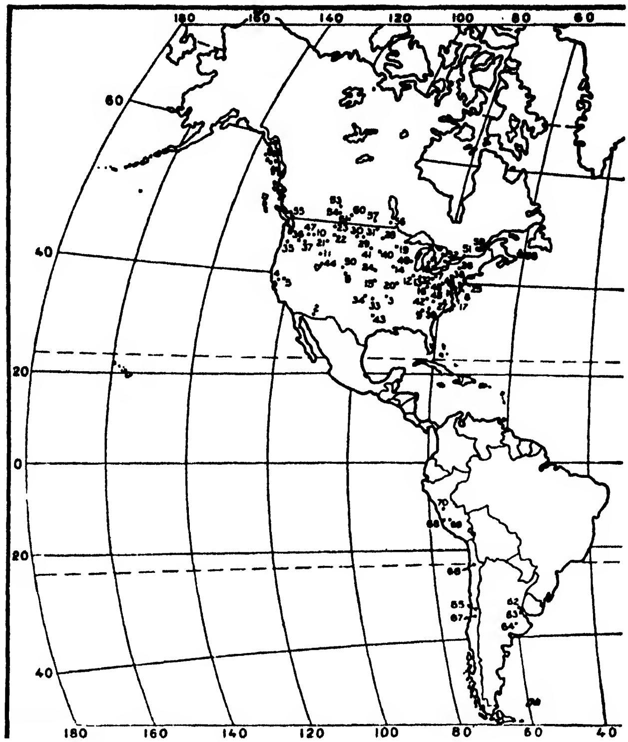


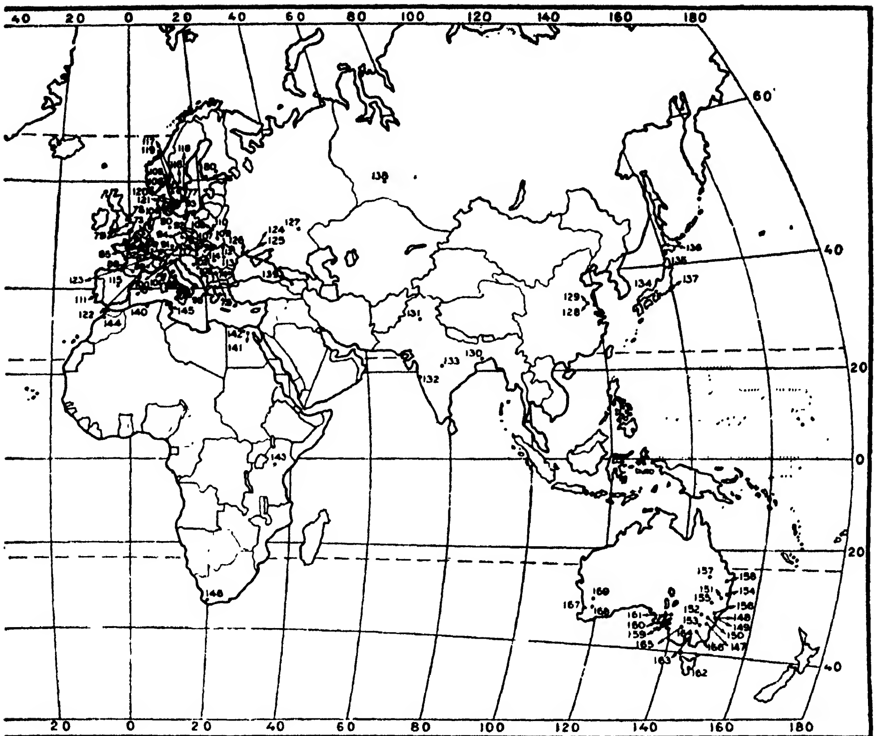
FIG. 28.—Location of wheat-breeding stations throughout the world. The numbers correspond to those in parentheses in the appendix (p. 277).

FIGURE 29.—E. F. Gaines, professor of genetics, State College of Washington, 1911- —, Pullman, Wash., breeder of Triplet, Ridit, Albit, and Hymar wheats.

1903 to 1922, the credit for originating Marquis and other important varieties is due. The development of Marquis wheat has stood for years as the greatest achievement in wheat-breeding history.

The distribution of the two early maturing wheats, Garnet and Reward, by the present Dominion cerealist, L. H. Newman, is an important contribution not only to Canada but to other countries as well, as Reward is recognized as one of the best varieties for high quality ever produced by wheat breeding. The development of two new varieties, Apex and Renown, has been announced recently by Canadian workers.

In addition to the Dominion and Provincial wheat breeders listed elsewhere, Seager Wheeler, of Rosthern, Saskatchewan, breeder of the Red Bobs, Supreme, Early Triumph, and Kitchener



varieties, must be mentioned as Canada's most outstanding private wheat breeder.

Mexico grows more than 2 million acres of wheat annually. Climate, soil, and plant diseases limit the production of wheat in that country. The principal types of wheat grown are common white and soft red winter. The white wheats are mostly spring varieties but are fall sown. Club wheats are occasionally grown. Among the common white wheats, Sonora, Defiance, Pacific Bluestem, and Hard Federation are important, the latter three varieties coming from the United States. Sonora, Barbon, Rojo, and Puebla are Mexican varieties of undetermined origin. It is not known to the writer whether any wheat breeding is being done in Mexico, since no report was received.

SOUTH AMERICA

Argentina is the most important wheat-producing country of South America. Barletta is probably the oldest and most widely grown variety. It is a hard red winter wheat. In recent years the native varieties have been partly replaced by Kanred, Blackhull, and Cheyenne, improved hard red winter wheats developed in the United States. The Argentine Department of Agriculture has given much attention to developing new varieties adapted to Argentine conditions. As a result of this work, the varieties Record, Universal, and San Martin have been developed. Raimundo Nieves, head of this plant-breeding work, and Enrique Klein, a private breeder, are the most prominent wheat breeders in Argentina.

FIGURE 30.—Charles E. Saunders, Dominion cerealist, 1903 to 1922, breeder of Marquis and other varieties of wheat, for which the British Government honored him with knighthood and the Canadian Government granted him a pension.

In Chile, white wheat is the predominant class of wheat grown. Certain Australian varieties such as Florence are very important. In the southern zone, white club (*Triticum compactum*) wheat is grown on account of its resistance to excessive rains. It is from here that the Big Club and Little Club wheats were reported introduced into the United States as early as 1866, forming the foundation of club wheat production and providing the germ plasm for further club wheat improvement in this country.

In Peru, wheat is grown at high elevations of 10,000 feet or more, and it is also subject to great changes in temperature and rainfall. Heavy rainfall and high humidity frequently aid in causing severe rust losses. Here Hope wheat was reported to have rusted heavily in one season, while Khapli emmer was not injured. Whether the infection of Hope wheat was due to a different physiologic form of rust to which it was susceptible in the mature stage, or to extremely favorable environmental conditions, has not been proved. Further reports of heavy infection on Hope wheat under the very favorable conditions for rust infection in Peru have not been received.

EUROPE

Wheat breeding in Europe is of course much older, and in some countries is more intensively pursued, than in the United States. Fourteen European countries are listed as growing annually over a million acres of wheat each.

The Union of Soviet Socialist Republics with 43 million acres of wheat heads the list. This average acreage is less than half that which has been grown in some years, and the possibilities for wheat production are much greater than the acreage figures available for any 1 year indicate. New varieties adapted to vast undeveloped areas are needed. In a memorandum to the writer, N. I. Vavilov, director of the Institute of Plant Industry, Leningrad, has given a summary of the wheat breeding work of that country as follows:

The wheat lands of the U. S. S. R. being located under conditions of a continental climate, Soviet wheat breeders have directed their attention chiefly to the selection and production of varieties resistant to drought, to cold, and to various diseases, as well as varieties with high-quality grain. At least thirty plant-breeding stations are now working on wheat selection. Most of the selected varieties were produced by the method of individual selection from local or foreign populations. Many of our best winter varieties have been selected

from Hungarian and Polish winter varieties of wheat. The Hungarian Banat wheat has given origin to some of our best winter types, such as Ukrainka, Moscow 02411, Durable, Stepnyachka. Banat wheat was introduced many years ago from Hungary and Poland, and widely distributed throughout the Ukraine. One of our most hardy winter varieties, characterized by exceptional cold endurance, Lutescens 0329, was obtained by selection from populations of the Polish Sandomirka wheat. Spring varieties of ordinary and durum wheat have been produced chiefly from local populations.

Only during the past two decades has any considerable attention been given to crossing, but in this field, especially as regards distant hybridization of species and genera, Soviet plant-breeders have already accomplished much.

Scientific wheat breeding in our country dates from 1902, when it was started at the Moscow Agricultural Academy in Petrovskaya-Rasomovskaya. In 1908 the Bureau of Applied Botany of the Ministry of Agriculture began the study of local varieties of wheat all over the country. Our theoretical studies of variation on the basis of the "law of homologous series in variation" convinced us of the necessity of a thorough study of all cultivated and wild species and closely related genera. It became quite evident from our theoretical studies that our knowledge was particularly inadequate as regards the wheats of old, primitive regions, such as Afghanistan, Abyssinia, the Mediterranean countries, and India. In 1916 we made our first expeditions to study and collect wheat varieties from all over the world. This work was especially developed beginning with 1923. Many expeditions were sent out to the primary regions, and about sixty-five different countries were thoroughly studied with respect to wheat varieties as well as to other crops of importance to our country. Not less than 31,000 specimens of wheat have been collected, with definite ecological and geographical data, and all this immense amount of material has been studied by all modern methods of taxonomy, cytology, and genetics. These studies have provided a new geographical and botanical basis for plant breeding.

The facts brought out by these investigations have surpassed all expectations. It was found that, although botanists and agronomists have been studying wheat for not less than 200 years, our knowledge of the initial material even of such an important crop is very fragmentary. At least twice as many species are now known as in 1921, the date of the appearance of the best world monograph on wheat, that of Dr. Percival. The number of botanical varieties of wheat is now nearly four times that known to Dr. Percival. In Dr. Percival's monograph only 195 botanical varieties are described (in the sense of Koernicke); now we have determined the whole number of botanical varieties of wheat, not less than 650.

The regions where botanical varieties of wheat have accumulated in greatest diversity have been established. Here are found many species and varieties with very important characters, such as immunity to rust, smut, mildew, and Swedish and Hessian flies. The Mediterranean types of durum wheat have proved to be of extremely high grade from the point of view of milling and baking qualities. It was established definitely that the range of variation of durum types, the 28-chromosome group, is greater than that of the 42-chromosome group, ordinary wheat. During our studies we have discovered many new, interesting types, such as beardless durum wheat in Abyssinia.

A new species of wheat discovered in Transcaucasia, *Triticum persicum*, has proved to be of great interest from the point of view of its frost-resistance and its resistance to various diseases.

There are four new publications which would be of help to those desiring to follow in more detail the work which has been done in recent years in the Soviet Union on wheat studies—the taxonomy, genetics, and breeding of wheat:

Vavilov, N. I.—Scientific Bases of Wheat Breeding (in press).

Flaksberger, K. A.—The Wheat Plant—A Monograph. 1935.

" " —Key to the Wheats of the Globe (in press).

Allocation of the Best Varieties of Grain Crops. Pub. by the Institute of Plant Industry. 1935.

It is very important to note that under the socialist system of the Soviet Union, the introduction into cultivation on a wide scale of new, selected varieties is based on the findings of the State Variety-Testing Network of the Institute of Plant Industry. This is an extensive network, embracing in 1935, 192 experimental fields distributed over the entire country, and, in addition, a secondary network of smaller experimental fields. The varietal tests cover not only yield data but also a study of the chemical attributes, milling and baking qualities, reaction to diseases, and other characters. The results of these varietal tests are published in a series of monographs.

France, with an average area of about 13½ million acres in wheat, is the second largest wheat-growing country of Europe. Much of the wheat breeding is done by private agencies or breeders, such as Louis de Vilmorin of the Vilmorin-Andrieux Co. of Paris. This company distributed the Allies and Aurore varieties, the latter said to be the earliest and most productive of spring wheats. Other varieties, such as Le Ceres, Blé de Silene, and Hybride Inversable, were distributed by Hector Gagneux, seedsman, Villiers-Saint Georges. Wheat breeding also is being done at many agricultural institutions, several of which are listed, E. Schribaux and Charles Crepin being among the most successful and best known breeders.

Italy ranks third among the European countries in wheat acreage. Wheat is grown under a wide variety of conditions. Approximately 20 or 25 percent of the production consists of durum wheat. Most of the wheat grown in Italy, however, is of the common spring type but is fall sown. Ardito, a bearded soft red variety, is grown widely throughout Italy and in other countries.

Signor Nazareno Strampelli, director of the Royal Experiment Station of Wheat Growing at Rieti and of the National Institute of Genetics as related to the Cultivation of Cereals in Rome, is Italy's most famous wheat breeder. He has bred a large number of early-maturing, high-yielding wheats. While no report has been obtained directly from him, his publications show that Ardito, Fausto, Sestini, Mentana, Villa Glori, Edda, Balilla, Battisti, Filzi, Oberdan, Rosmondo, Damiano, Chiesa, Fieramosca, Fanfulla and other varieties are of his breeding. Concerning the merits and advantages of his early maturing wheats Strampelli (*97, p. 6*) says:

> I have just stated that my early wheats have absolutely confuted the old idea that early maturation and high yielding capacity are mutually incompatible. The fact is that these wheats of mine, though ripening from ten to twenty, or even twenty-five, days earlier than the common wheat varieties of an earlier period, are able to give yields that are twice or three times higher and, as we shall see, they have reached yield levels that almost pass belief and may get higher.
>
> In addition, they all have, to a greater or less degree, a high capacity of resistance to such harmful influences as rusts and lodging and, as the result of their early ripening, they nearly always escape the risk of blast, which more readily attacks the slower maturing varieties, while at the same time their grain possesses excellent characteristics, from the point of view of milling requirements and of food value.

Spain ranks fourth among the European countries in wheat acreage, and production is influenced to a large extent by the relief of the country. Common white wheats predominate in the humid intermediate areas, while wheats of the poulard and durum classes are grown in the warm, dry Mediterranean territory of the south and east. Efforts are being made to obtain wheats of stronger quality than the native varieties and able to withstand the prevailing climatic conditions of the different sections. The American varieties, Marquis and Kanred, are being used as parents in crosses. The native varieties of greatest commercial importance in Spain are Aragon 6 Candeal de Monte, Candeal de la Sagra, and Candeal Fino, white winter wheats. The Candeal varieties are common wheats. Others of importance are Grenadino (durum) and Baza (poulard). Leading Spanish wheat breeders are Señor Marcelino de Arana y Tranco, Francisco Silva, and Señor Fernando Silvela de Tordesilla, of the Institute Cerealicul-

tura La Moncloa, Casa de Oficios, Madrid. Señor de Tordesilla was formerly in the Spanish agricultural attaché's office in Washington.

Rumania raises both winter and spring wheat. The principal area of production is along the Danube River. Two varieties, Samanta 117 and Samanta 1252, were developed by the Samanta Society for Seed and Plant Selections, Cenad (Banat). Stefan Popescu and N. Saulescu, from different institutions, are leading wheat breeders.

Yugoslavia, with nearly 4 million acres of wheat annually, has not reported on the work of the wheat-breeding stations or of wheat breeders requested from Ministarstvo Poljopririede, Beograd (Ministry of Agriculture, Belgrade).

Germany, with about 3½ million acres in wheat annually, does not produce sufficient for home demands, and it is necessary to import large quantities. Wheat production is confined largely to the common winter wheats, although some spelt is grown. Through the selection of winter-resistant types, the area of fall-sown wheat now extends to the extreme north of the Prussian plain. When the cultivation of winter wheats becomes impossible, they are replaced by spring varieties.

The varieties of winter wheat grown in Germany are mostly of local origin, modified by selection to withstand adverse climatic conditions—such types as Squarehead (Dickkopf selected). Hybrids, obtained by crossing Dickkopf with local varieties, and imported types of Swedish origin, such as the variety Pansar, also are grown.

John Voss, of the Biologische Reichsanstalt für Land- und Forstwirtschaft, replying to the questionnaire on wheat improvement, states:

> Plant breeding in Germany is conducted almost entirely under private auspices, which are affiliated with the Imperial Society of the German Plant Breeding Management (Reichsverband der deutschen Pflanzenzüchttelriebe) Berlin W. 35, Lützowstrasse 109/110.

He furnished a publication of the society containing the names of 182 registered varieties of wheat, 27 of which he had marked as being the most important commercially or as having superior germ plasm for one character or another of most value in future breeding for German conditions. Among the breeders is J. Ackermann, Gut Irlbach, Post Strasskirchen, Niederbay, producer of the Braunweizen Bayernkönig, Viktoria, Isaria, and Danubia varieties. Others are W. Rimpau, Langenstein, Kr. Halberstadt, and K. v. Rümker, Emersleben, Kreis Halberstadt, breeders of important varieties, such as Rimpaus Schlanstedter and v. Rümkers Früher S. D. K.

In addition to the work of these and many other private breeders, practical breeding and genetic research work with wheat is being conducted at the public institutions listed elsewhere.

Hungary has more than 3 million acres in wheat annually. Red winter wheats are grown principally. Such varieties as Banat, Theiss, Weissenberg, Pesterboden, and Budapest were introduced into the United States from Hungary by the United States Department of Agriculture in 1900. In the United States these semihard winter

wheats have stronger straw than the Crimean and Turkey wheats from Russia. The Hungarian varieties proved best adapted in Iowa, and several important varieties were developed from them by selection. The native wheats in Hungary now are said to be Eszterhaza, Hatran, Bankup, Szekacs, and Ozora. The first two varieties are soft red winter, the third hard red winter, and the others spring. These are being improved by selection in Hungary, according to John Suranyi, agronomist of the Agricultural Experiment Station for Plant Industry, Magyarovar.

Poland, an important hard wheat-producing country, grows both winter and spring varieties. Important breeding work is being conducted by Edward Malinowski and his associates at the College of Agriculture, Warsaw, as well as at the other institutions listed. Poland is the original source of Red Fife wheat, from which developed the hard red spring wheat industry of Canada and the United States.

T. Pilch, chief of the section of economic policy, Ministerstwo Rolnictwa I Reform Rolnych, Warszawa, has reported as follows on the wheat-breeding work in Poland:

> The first more or less precise data concerning the improvement of wheat in the modern meaning of this word, date from 1860. They consisted chiefly in a selection of varieties among the existing local species by means of individual choice. This method gave good results for a long time, especially with regard to self-fertilizing plants, until the most valuable types among Polish varieties of wheat were selected.
>
> Later on, when new knowledge of heredity was secured, and as the development along the line of individual selection stopped progressively, genetic methods were applied in Poland. By means of crossing different varieties of wheat among themselves producers can reach individual purposes.
>
> Not long ago in Poland endeavors were made aiming only at getting the largest crop from a unity of field surface without paying any special attention to the baking value of the grain. Now the breeders' desire is to get the best quality of grain and they try conjointly with the State Scientific Institute of Rural Economics at Pulawy "Państwowy Instytut Naukowego Gospodarstwa Wiejskiego w Pulawach" to secure the most valuable varieties for the baking point of view giving simultaneously the highest crop from a unity of surface. The fitogenetic problem is, of course, an integral part of the final aim, which must be reached.

Bulgaria, with nearly 2½ million acres in wheat annually, carries on extensive breeding work, especially at the State agricultural experiment station at Obraztzor Tchiflik, Ruse, where G. Proitcheff is director. He has reported the development of winter wheats nos. 7, 14, 16, 84, and 159, the most widely distributed wheat in Bulgaria, and states:

> Apart from these sorts, there are other strains, too, produced by the state institutions for wheat improvement, which are in the stage of comparative test and are not yet commercially grown.
>
> The method of wheat improvement in our country is chiefly the individual plant selection from our old commercial varieties, rich in strains of superior characters, winter hardiness, black stem rust resistance, etc. The introductions from the foreign countries much in vogue at the beginning are no longer practiced since the isolation of our present sorts from the local varieties.
>
> Hybridization as a method of wheat breeding is employed only in special cases.

In England and throughout Great Britain, excessive rains and insufficient sunshine contribute to make the wheat of low quality.

The soft high-yielding varieties grown also tend to have low baking quality. Yeoman, bred by R. H. Biffen (fig. 31), Cambridge University, an outstanding wheat breeder, from the cross Browick × Red Fife, is unique among English wheats as the only variety that produces flour suitable for making bread without the addition of strong wheats from abroad. The Little Joss (1912), Yeoman I (1917), and Yeoman II (1920) wheats developed by Biffen now constitute a large percentage of the English crop.

Another outstanding wheat breeder in England is John Percival, of the University of Reading, who developed the Fox and other improved varieties. He also has written the largest and best monograph on wheat, and has made many other important contributions. Additional varieties of importance among English wheats are Squarehead, Squareheads Master, Chevalier, and Crown, soft red winter; the white winter wheat Wilhelmina, from the Netherlands; and the Cone and Rivet poulard wheats. These poulard wheats seem to be peculiarly well adapted to conditions in England.

FIGURE 31.—Rowland H. Biffen, director of Plant Breeding Institute, University of Cambridge, England; breeder of Yeoman wheat and pioneer post-Mendelian wheat geneticist. His early work with stripe rust and grain quality is most important.

Czechoslovakia grows about 1½ million acres of wheat, mostly winter varieties. Important among these varieties are Dioseg No. 2, Dregr Bohemian No. 12, and Sebek No. 11. Jaroslav Peklo, Technical University, Prague, is conducting important breeding and genetic research work, using the Bohemian wheat called Tinonice, the Russian Kubanka, and the Grenadier II and Kotte Grenadier from Svalöf, Sweden, as parents. He distributed the U. P. wheat in 1933 (U = the experimental farm at Uhřīněves and P = Dr. Peklo). This wheat is high yielding, winter hardy, has good kernel quality, and is resistant to yellow rust (*Puccinia glumarum*).

In Portugal, as in Spain, wheat production is influenced by the climate and relief of the country. Along the Atlantic coast excessive rains are detrimental. Common winter wheats predominate. Temporao de Coruche, a rust-resistant winter wheat, is the type of milling wheat most suitable, and it is cultivated with success throughout the country. Other important varieties are Nacional, a poulard, and Mourisco, a durum.

Greece, with over a million acres of wheat, carries on important breeding work at the Experiment Station for the Improvement of Plants, Salonika. J. S. Papadakis, director, has reported in detail on the extensive work being conducted there. Many introductions, selections, and hybrid strains have been distributed. Among the principal commercial varieties grown are Mentana from Italy and

Canberra from Australia. Selections Mykine, Xylocastro (common), and Eretria (durum) from Greek populations, and hybrids T. 3130 (durum), T. 856F, and T. 9234 (common), have been distributed. The T. 3130 is from Kentradi (Greek durum wheat) × *T. villosum;* T. 8567 from Federation (Australian) × Ardito (Italian); and T. 9234 from Florence × Ardito. In the breeding work emphasis is placed on early maturity, drought and rust resistance, and the necessity of growing large populations.

Sweden, although averaging less than a million acres of wheat annually, carries on important and world-famous pioneering breeding work, and any review of European wheat breeding would not be complete without emphasis on the work of the Svalöf station and other institutions in Sweden. At Svalöf the work of N. H. Nilsson-Ehle, director, Hjalmer Nilsson, and the others listed elsewhere is outstanding. Newman (*71*) has reviewed the early wheat breeding of the Swedish Seed Association. For this report I. Granhall has furnished a summary showing the records of 40 wheat varieties developed and distributed for commercial growing from that institution from 1891 to the present time; also 9 varieties developed at the Weibullsholm Plant Breeding Institute.

Some of the best and most widely grown are Grenadier I (1891), Extra Squarehead I (1892), Sol I (1892), Pansar I (1903), Extra Squarehead III (1907), Riddar (1912), Crown (1914), Drott (1916), and Scandia (1922). These and other winter wheats have been selected or bred by hybridization for improvement in some plant character or disease reaction. Among the spring wheats, Pearl (1892) and Svalöfs Kolben (1898), resembling Red Fife, were developed by selection, and Ruby (1906), Diamond (1911), and Fylgia (1919) from hybridization. Among the varieties developed at Landskrona are Iduna (1904), Anchor (1911), Jarl (1914), and Ergo (1922), bred by B. Kajanus or S. O. Berg.

ASIA

Vast areas of undeveloped lands suitable for growing wheat are within the boundaries of the Union of Soviet Socialist Republics, and several wheat-breeding stations are located in Siberia.

China grows about 46 million acres of wheat annually. Statistics on wheat production there are just becoming available, and wheat-breeding work at public institutions has also been started only recently. For centuries the Chinese farmers have been selecting wheat, partly for ease of threshing, which was done by hand. Most of the wheat varieties grown in China, therefore, shatter easily, and they are mostly of the soft red winter type. H. H. Love and others from Cornell University, Ithaca, N. Y., have spent several years in China, starting and organizing the wheat-breeding work there. Concerning his work in China, Love has reported as follows:

> Relative to the work done by the College of Agriculture and Forestry of the University of Nanking, Dr. T. H. Shen has been the Chinese in charge of this work, much of which has been done in cooperation with those of us from Cornell who have gone out from time to time.
>
> The program of work at Nanking has been a rather large one, such that cooperation was arranged with a number of stations in different parts of China. The important cooperating stations working with the University of Nanking are the

Presbyterian Mission Station, Nanhsuchow, China; the Kiangsu Provincial Wheat Experiment Station, Hsuchow, Kiangsu; the Southern Baptist Mission Station, Kaifeng, Honan; the Yenching Crop Improvement Station, Yenching University, Peiping; and the Agricultural Experiment Station at Cheeloo University, Tsinan, Shantung.

At the main station at Nanking an improved strain of wheat, Nanking #26, was distributed several years ago. It proved to be considerably better than the farmers' varieties. Recently Nanking #2905 has been distributed and this yields about 32 percent more than the farmers' varieties. It is a very good variety of wheat.

At the Station at Nanhsuchow they have distributed Nanhsuchow #61. It is much better than the average farmer's varieties grown in that community.

At the Kaifeng Station the variety "Sallee," Kaifeng #24, is being distributed. This is a very good yielding wheat of high quality. In addition to this work, Dr. H. W. Li, working at the Honan Provincial School, Kaifeng, Honan, has developed a variety which he states in a recent letter is very promising.

Wheat investigations are being conducted at the Chekiang Agricultural Experiment Station at Hangchow, Chekiang. The leader of this work is Mr. T. S. Mo, the Director of the Experiment Station. Some work in wheat breeding was also conducted by Mr. Mo at the National Central University at Nanking, China.

A large program of wheat improvement is now under way at the new National Agricultural Research Bureau, Shaolingwei, Nanking. This was the Bureau that I helped to organize and I developed the wheat breeding program for them.

India is the next largest wheat-growing country in Asia. The principal classes are common white and durum. Pusa 4 is a very early spring wheat grown on the dry lands and also under irrigation in the North-West Frontier Province. Federation, from Australia, also is a popular spring variety. Bansi and Howrah are leading durum varieties, and Kathia, a poulard, is grown. A. Howard and the late Mrs. G. L. C. Howard, formerly with the Department of Agriculture, Calcutta, have long been prominent among India's wheat breeders, and indeed among the wheat breeders of the world. The two wheats, Pusa 4 and Pusa 12, held a leading position in India for many years. Pusa 52 was produced by the Howards from a cross between a Punjab wheat (Punjab type 9) and Pusa 6. Pusa 101, another hybrid produced by the Howards, has proved a successful early maturing wheat. Pusa 80–5, produced by crossing Pusa 4 with Pusa 6, also is widely grown. According to Shaw (*91*) these wheats "owe their spread and popularity primarily to their yielding power and the high quality of their grain." F. J. F. Shaw, director of the Imperial Institute of Agricultural Research, Pusa, further states:

> The improvement of India wheat was first directed towards increasing the yield per acre; more recently attention has been given to the improvement of quality, with the object of placing on the market a grain which would compete with the "hard" wheats exported from Canada and the United States of America.

In the other provinces of India new wheats also have been developed to meet local conditions. In the Punjab, Punjab 8A and hybrids 409 and 518 are improved strains now grown.

Turkey, with over 7 million acres of wheat annually, has not reported on any breeding work and very little is known regarding the classes and varieties of wheat grown there or what breeding work is in progress. Some durum wheat is known to be grown.

Japan, with over a million acres of wheat, is doing much intensive work on wheat improvement, especially in the fields of agronomy and cytology. Some of the principal varieties grown are Sapporo Haru-

komuki No. 9 and No. 10, from the Hokushu Agricultural Experiment Station at Sapporo, where Takatsugu Abiko is agronomist. The American variety Martin Amber is grown rather extensively. The Kumanoto Agricultural Experiment Station at Kumanoto, where S. Tanji is director, and the Imperial Agricultural Experiment Station, H. Ando, director, at Nishigahara, Tokyo, also have distributed new varieties, such as Soshu, Daruma, and Igachikugo. The native wheat grown is mostly soft red winter wheat, but some of the newer varieties are white winter and hard red and hard white spring. Other institutions in Japan where important cytological work with wheat is conducted are listed elsewhere.

AFRICA

Algeria, Morocco, Egypt, and Tunisia are the leading wheat-growing countries of Africa. Together these countries grow about 10 million acres of wheat annually.

Algeria, with 3½ million acres, largely grows durum wheats. In 1902 Scofield (*90*) classified and described the Algerian durum wheats for the United States Department of Agriculture. From this country the Peliss and Kahla varieties were introduced and became commercially important in the United States. Some common and some poulard wheat is grown in Algeria. The Fretes, a very drought-resistant wheat, was introduced from there in 1901 and was commercially grown in California. Some of the Algerian varieties now grown are Biskri, Namira, Mahmoudi AG[3], Touggourt, and Kantara, durum; Blé de Oasis, Piccolo, and Richelle, common; and the Allemond poulard. L. Ducellier is a breeder.

Morocco, with nearly 2½ million acres, also grows mostly durum wheat. The variety Dredria is chiefly in demand. Emil Miege is in charge of the breeding work at Rabat.

Egypt grows about 1½ million acres of wheat annually, almost entirely under irrigation and from fall seeding. The Ministry of Agriculture at Cairo has conducted wheat improvement work. B. G. C. Bolland, the earliest breeder, developed the Hindi D, Hindi 12, and Beladi 42 by selection, from native Egyptian seed. Hindi D is the most widely grown variety and has white kernels of opaque character. Beladi 42 is grown extensively in upper Egypt. Further selections, Hindi 62 and Beladi 116, have been distributed by G. P. Morris. All Egyptian wheats are of spring habit, although they are fall-sown.

Tunisia has nearly 1½ millon acres of wheat, which contends with drought, hot winds, and in some seasons rust. Until recently durum wheat occupied the chief place, but the yields of common white wheat varieties are now better and they are becoming widely grown. Among the white spring wheats used are Richelle, Florence, and Irakie. Some hard red winter wheat is grown also, the varieties being Blé de Mahon and Barletta. Among the most common durum wheats are Mahmoudi, Biskri, and Hamira. In Tunisia a wheat-breeding station is maintained with F. Boeuf in charge.

Australia grows over 10 million acres of wheat annually, ranking tenth among the countries of the world in acreage. New South Wales has the largest acreage, closely followed by the States of Victoria, South Australia, and West Australia. The varieties grown are very numerous. They are common white wheats of spring habit, though fall-sown.

Much wheat-breeding work has been intensively conducted in Australia, both by private breeders and at many public institutions. The institutions where the leading wheat work is now carried on, together with the principal workers, are listed elsewhere, and it is regretted that complete publication of many detailed reports received cannot be presented in this article. The late William J. Farrer (fig. 32), of New South Wales, is Australia's most famous wheat breeder, and one of the world's pioneers in plant breeding. He produced many varieties, including Federation and Bunyip, which are now important in the United States.

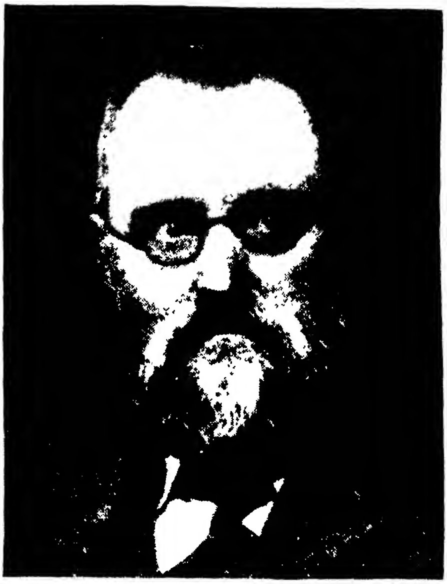


FIGURE 32.—William J. Farrer, New South Wales, Australia originator of Federation and Bunyip wheats, and world-famous pre-Mendelian wheat breeder. Deceased April 1906

These and other varieties of Farrer's breeding have long been the principal wheat varieties grown in Australia and also in many other countries. Great improvements in the wheats of Australia have taken place in the past 50 years. Concerning the early work, H. Wenholz, director of plant breeding, Department of Agriculture, Sydney, New South Wales, has written: [4]

At the beginning of this period, the varietal nomenclature of wheat was haphazard, uncertain and confusing, but work by plant breeders beginning with Farrer has served not only to give definiteness and character to wheat varieties and their nomenclature, but has also been attended with the development of greater specialization in the suitability of varieties for particular climatic and other environmental conditions. In more recent years, the evolution of varieties specifically resistant to diseases such as flagsmut, stem rust, etc., has become a more important practical development, and most recently improvement in quality or baking strength is now being sought in Australian wheat.

This work in the improvement of the yield, quality, resistance to disease and other field characters of varieties of wheat which are designed to increase the net return per acre to the grower is one of the most important national tasks undertaken by State Departments of Agriculture.

Wheat breeders in Australia have been notably successful in these objectives as is shown by the following record of achievements accomplished in this field.

Farrer Varieties

Improvement in Australian wheat was pioneered by the late William Farrer, whose monumental work is so well known. When Farrer began his self-appointed task in 1886, wheat growing was chiefly confined to the Tablelands and cooler

[4] WENHOLZ, H. IMPROVEMENT IN AUSTRALIAN WHEAT. MILESTONES IN ITS PROGRESS. Unpublished paper furnished the writer.

slopes, where conditions were favourable for the culture of late maturing wheats from which heavy yields were obtained when the crops were not affected by stem rust.

This rust, however, took a very large toll of the wheat crops in some years, and Farrer's first objective was to produce varieties which were more resistant to this disease. He found that earlier maturing varieties did not suffer so greatly from the ravages of stem rust, and by the breeding of such varieties also he was able to extend the wheat belt into hotter and drier districts in Australia, where stem rust was not a serious factor.

At the time when Farrer began his wheat breeding work there were practically no early maturing wheats under cultivation in Australia. Most of the wheats being grown were late maturing varieties which had been brought by the early colonists from England and had become more or less acclimatized to the favorable conditions of the Tablelands and the coolest parts of the Slopes. One of Farrer's first acts, therefore, was to introduce early maturing wheats from the hot climate of India.

Farrer had another important objective in the improvement of Australian wheat, viz., the improvement of the gluten content and strength of the flour, in order to make a better loaf. For this purpose he also introduced the Fife wheats from Canada which were of high quality in these characters.

Farrer first crossed the Fife wheats with the Indian wheats, but he soon realized that he would have to use the Purple Straws to introduce the character of productiveness. He achieved a remarkable success with this triple combination in the variety Federation, which was produced in 1901 and was so aptly and deservedly named. By 1910, Federation had become the most popular variety in Australia and it was so remarkably productive under a wide range of conditions that even in 1925 it was still the leading wheat in Australia. Other Farrer wheats which became widely grown were Florence, Rymer, Bobs, Comeback, Bunyip, Firbank, Cleveland, Thew, Tarragon, John Brown, Warren, Plover, Schneider, Jumbuck, Jonathan, Genoa, Bomen and Clarendon.

None of these varieties ever approached Federation in popularity and general value in Australia, but some of them, such as Rymer, Firbank, Cleveland and Florence, have been of lasting merit and are still grown commercially to some extent.

An adequate review of all of Farrer's work and the present wheat improvement work under the direction of Dr. Wenholz and others at the many institutions listed would require a book in itself. Wenholz is now engaged in the task of preparing just such a review.

Progress in Genetic Research With the Wheat Plant

THE importance of genetics in solving the underlying principles of inheritance, thus facilitating more efficient breeding operations, cannot be overemphasized. Soon after Mendel's classic publication (*69*) [5] was rediscovered in 1900, Bateson coined the word "genetics,"

[5] That Mendel had a clearer understanding of the problem than any of his predecessors was shown by Iltis (*52*) and more recently by Harbou (*44*) in a biographical sketch. Mendel's point of view was clearly expressed in the foreword of his publication, published in 1866: "That it has not so far been possible to establish a universal law for the formation and development of hybrids no one, familiar with the extent of the problem and the difficulties with which experiments of this kind have to contend, can wonder. An entirely conclusive judgment of the question cannot be given until detailed experiments have been made on the most diversified families of plants. A careful consideration of the works hitherto undertaken will lead to the conclusion that so far none of the numerous experiments have been carried to such an extent or in such a way as to make possible a determination of the number of different forms in which the offspring of the hybrids appear or to arrange these forms with certainty within the different generations so as to ascertain their numerical relation. At any rate a great deal of courage is required to undertake such an extensive work. It seems, however, to be the only possible way to reach the solution of a question which is undoubtedly of no small importance in its bearing upon the evolutionary history of organic forms. The present work describes the result of such a detailed experiment. It is deliberately limited to a small group of plants and is now, after eight years, practically concluded. Whether the plan upon which the individual experiments have been arranged and conducted is in harmony with the problem to be solved must be submitted to the kind judgment of the public."

and immediately wide interest developed in the science. Genetics is the study of heredity and variation among related organisms. The reactions of an organism to environment are included in genetics.

In 1929 Matsuura (*66*) of Japan, published A Bibliographical Monograph on Plant Genetics in which the work of more than 500 investigators was listed. This represented the first quarter of a century of the application of Mendel's laws to problems of heredity. In 1934, 5 years later, 10,155 publications, 1,141 on wheat alone, were listed in a Bibliography of Plant Genetics assembled in the Library of the United States Department of Agriculture (*107*).

THE importance of genetics in solving the underlying principles of inheritance, thus facilitating more efficient breeding operations, cannot be overemphasized. Soon after Mendel's classic publication was rediscovered at the turn of the century, Bateson coined the word "genetics," and immediately wide interest developed in the science. A third of a century later, in 1934, 10,155 publications were listed in a Bibliography of Plant Genetics assembled by the Library of the United States Department of Agriculture. This large number did not include publications on animal genetics. While much work has been accomplished with wheat, the peak of research surely has not yet been reached. Many problems remain to be solved, and even greater results than those obtained in the past may be expected in the future.

Many of the characters and qualities of the wheat plant have been studied genetically. Mendelism has furnished the plan of inheritance.

Mendel's work dealt with unit characters, dominance, segregation, and recombination as underlying principles. While unit characters have not proved to be so simple in wheat as was at first thought, and dominance is imperfect or absent (intermediate) in some cases, the single character is still the foundation for studying wheat inheritance, and dominance the primary basis for genetic interpretations. The first simple 3:1 and 1:2:1 segregating ratios are by comparison with other genetic ratios of the present time as the letters A B C are to the entire alphabet, or H_2O to other chemical formulas. Desired recombinations of factors are always the hope of the breeder, and he is successful when, through these recombinations, the valued characters

of the parents are transferred to the progeny. One of the most interesting and valuable results from recombinations in wheat crosses is the frequent occurrence of transgressive segregation due to complementary factors.

It is not the purpose of this article to present a monograph or bibliography of wheat genetics but rather to discuss some of the more important results obtained with certain characters and to suggest further problems. While much genetic work has been accomplished, the peak of research with wheat surely has not yet been reached, and with financial support and administrative interest, even greater results than those obtained in the past may be expected. Many problems remain to be solved. It is the desire of the writer to show the fundamental relation between genetic research and practical breeding. But fruitful as the results of genetic research have been, we should not delude ourselves into thinking that the knowledge they have yielded is enough. In practical breeding, genetics cannot stand alone as a method of investigation; cytology, physiology, pathology, and mathematics are valuable aids in interpreting results.

INHERITANCE OF QUALITATIVE CHARACTERS

In the wheat plant, as in other organisms, study of the inheritance of qualitative characters is usually simpler than study of quantitative characters. The reason for this is that qualitative characters are the most easily distinguished characters of the wheat plant and they may readily be placed in distinct classes or groups. Principal among such characters are color of kernel and awnedness. The inheritance of these will be reviewed. Other qualitative characters are dwarf and normal plants, the presence or absence of the ligule, color and covering of the glumes, color of straw, etc.

Color of Kernel

Kernel color was early recognized as an important character in wheat varieties and thus it was among the first used for a study of Mendelian inheritance in wheat. Most varieties of wheat were observed to have either red or white kernels, although some Abyssinian durum wheats and emmers are purple.

In the early work (1905) by Biffen (*6*), red was found dominant to white in F_1 and segregated in a simple 3 : 1 ratio in F_2. Nilsson-Ehle (*73*) was the first to report crosses in F_2 giving 15 : 1 and 63 : 1 ratios of red-kerneled and white-kerneled plants, indicating the presence of two and three genetic factors. Many other workers, including Gaines (*37*) in this country, have since obtained similar ratios. From F_3 studies, the presence of 1, 2, or 3 independent genetic factors has been proved for red kernel color in different varieties. Nilsson-Ehle's theory was that, taken together, the three red color factors behave cumulatively, following the law of a trihybrid,[6] and increase the intensity of the red color. These and other early genetic studies have been of great value to wheat breeders working for improvement of varieties in both the red and white wheat classes. They partly explain the different shades of red observed in different varieties and show the ease or difficulty of obtaining the desired colors.

[6] A hybrid with three elements.

Harrington (*45*) reported that some strains of Red Bobs and Hard Red Calcutta contain two independently inherited factors for red color, while other strains contained only a single factor. The writer (*20*) found that in Marquis (red) × Hard Federation (white) crosses, two factors were most frequently present, but that in some crosses only a single-factor difference was present. In this cross and others studied, it has not been possible to recover the intensity of red color of the Marquis parent, although hundreds of F_2 plants and strains from the F_3 to the F_5 generations were carefully observed in a search for this. The fact that two different ratios were obtained indicates either that Marquis does not always have two dominant factors for kernel color or that the white Hard Federation parents differed in their genotype. The failure to recover the intense red color of the Marquis parent in some crosses with white wheats also is difficult to explain. These are some of the unsolved problems. The failure mentioned may be due to the presence of additional genetic factors, a certain combination of factors producing only light red color; or it may be that the known factors for red are not always independently inherited, or that they are not always cumulative in effect.

Percival (*78, p. 372*) pointed out Tschermak's observation that in some instances white-kerneled plants and strains have appeared among the descendants of hybrids between two different red-kerneled varieties. Hayes and Robertson (*49*) noted the frequency of the occurrence of white-kerneled plants in F_2 studies of Minturki × Marquis and Kanred × Marquis crosses, where the parents were both red-kerneled. From the data obtained, they concluded that Marquis has two factors for red color and that Minturki has one different red color factor. When recessives were present for all three factors, the result would be white kernels. The crosses approximated the ratio of 63 red-kerneled plants to 1 white-kerneled plant.

The usual result of crossing two white-kerneled wheats is the production of white-kerneled descendants in F_1 and all later generations. However, Percival (*78, p. 397*) has reported that Vilmorin obtained red-kerneled plants among the F_2 progeny of a hybrid made by crossing two white-kerneled strains of *Triticum polonicum* and *T. turgidum*. So far as known, this has never been repeated by other workers, nor have similar results been obtained by crossing two white-kerneled varieties within the same species. The results, if authentic, would indicate the presence of dominant genetic factors for white kernels.

With durum wheats we have an important problem, the solution of which may depend upon this point. Among the white-kerneled or amber-kerneled durums there are varieties such as Monad and Acme that have a dull rather than a bright appearance which is reflected in a gray color of semolina and macaroni, undesirable to the grain trade. In crosses of Pentad (red) with such desirable varieties as Mindum and Kubanka (amber), the dull-white strains are obtained. Out of many strains studied it has not been possible to recover any bright (amber) strains as desirable as the (amber) parents. This is another genetic problem, the solution of which is of great economic importance. If from crosses between two white durum strains (dull and bright) red-kerneled plants and strains could be obtained, as in Vilmorin's work, it would prove that there are dominant factors or complementary factors for white, and this might aid in solving the problem of getting the desired bright color.

Purple kernel color, as reported by Percival (*78*), is said to be due to an anthocyanin pigment in the "chlorophyll" or "cross layer" of the pericarp rather than in the testa, as with red wheats.[7] While this may be true for emmer, it has not been completely determined whether it is true for durum wheats. Percival (*78*) shows that Caporn studied the inheritance of purple kernel color in a cross made by Biffen between *Triticum polonicum* (white, Polish) and *T. dicoccum* (purple, emmer) varieties. F_1 grains were all purple. In F_2 the plants were separated into three classes for color: (1) Purple, (2) streaked, and (3) white. The proportion did not approach any definite genetic ratio, the majority being uncolored or white. The white-kerneled plants appeared to be of two kinds, (1) breeding true and (2) segregating. Segregation in F_3 did not support the results found in F_2, indicating different causes and a very complicated inheritance.

Other workers also have studied the inheritance of purple color with indifferent results. Most crosses have been between common wheat and emmer. These species crosses involved sterility and other difficulties. Clark and G. Smith [8] studied durum crosses of purple and white varieties without sterility being involved. Due to loss of many of the strains by rust, however, the results were not complete. A striking point observed was that homozygous red strains were obtained, differing from both parents. The white color was recessive and there was an intermediate color showing partly purple and partly red. In a durum cross of purple and red-kerneled varieties it was also possible to classify the plants into three classes: (1) Purple, (2) red, and (3) purple red. The durum crosses gave indications that the purple was in the testa layer with the red and that there were at least two color factors for red and one for purple. This is mentioned only as a lead for unsolved genetic problems on the color of wheat kernels.

Awnedness

In certain wheat-growing regions, such as the Great Plains, awns or beards are of considerable economic importance.[9] There also is often a preference by growers for awnless or awned varieties. They are characters most readily apparent in wheat and partly for this reason have frequently been used for genetic studies.

Varieties were early separated into two major groups on the basis of the awnedness character, namely, awnless and awned. In the early days it was thought that these characters were controlled by a single Mendelian factor. The first genetic study of the inheritance of awnedness in wheat hybrids was reported in 1905 by Biffen (*6*), who concluded that "the beardless condition is a dominant, the bearded, a recessive character." Other early workers obtained similar results in the first generation and in the second generation also, when the awnless and awned plants occurred in a simple Men-

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[7] Anthocyanin: A coloring matter found in the cell sap of many plants. It is red in the presence of acids, otherwise blue or violet. It occurs usually in portions most exposed to the light, and has been thought to serve as a screen against injurious rays while the tissues are young. The reddish or purple coloring seen in the spring foliage of the cherry, redbud, etc., is due to anthocyanin. (Webster). The testa is the tough outer seed coat, which in grain is fused with the pericarp or modified wall of the ovary.

[8] Unpublished data.

[9] Awned wheats do not tip burn as easily as awnless, and it is held that in some way the awns act as a buffer against wind and heat. The question needs to be cleared up by physiological research.

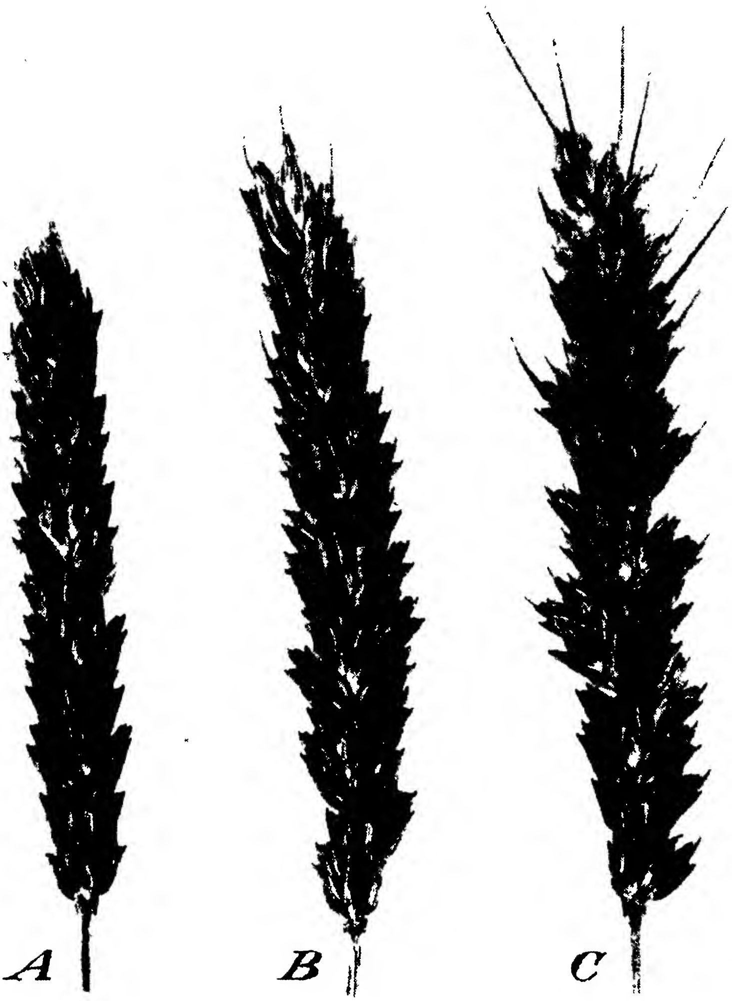

FIGURE 33.—Awnless (A), apically awnleted (B), and awnleted (C) classes of wheat.

delian ratio of 3 : 1. Saunders (86) first questioned the idea that the first generation between an awnless and an awned wheat always is awnless and maintained that the character of awns in the F_1 varies with the wheats used. Percival (78) later reported that F_2 segregation in numerous crosses approached a 1 : 2 : 1 ratio when intermediates occurred.

Evidently the awnless wheats referred to in most of the early genetic studies were tip-awned or awnleted. This so-called awnless group has been subdivided into awnless, apically awnleted, and awnleted, and all recent work has indicated that the correct interpretation of inheritance is based upon that classification. The awnless, apically awnleted, and awnleted classes are illustrated in figure 33.

Howard and Howard (*51*) were the first to work with the true awnless wheats, and they reported two factors as necessary for an interpretation of the inheritance of awns. They separated the F_2 progeny into six classes, and grouped all awned and tip-awned classes together as awned, which in comparison with the complete awnless gave a 15 : 1 ratio. They thus concluded that the awned character was dominant.

In similar studies between true awnless and fully awned parents, Clark (*13*) concluded from Hard-Federation × Kota and reciprocal crosses that the awnless condition was dominant, as the F_1, apically awnleted, approached more nearly the awnless than the awned parent, and also that two genetic factors could not entirely account for the breeding behavior in the F_2 and F_3 generations. Stewart (*94, 95, 96*) and other workers, however, have concluded from the results of other and similar crosses that the awned condition is dominant, following the work of Howard and Howard.

In crosses between awnless and awnleted wheats, the writer (*20*) has shown that two factors were necessary to explain satisfactorily the segregation of Marquis × Hard Federation hybrids into a 1 : 11 : 4 phenotypic ratio for awnless, apically awnleted, and awnleted classes, respectively. The inheritance of awnedness in wheat thus was found to be more complicated than the early workers reported.[10]

In this study it was concluded that there are as many as four genetic factors involved in the inheritance of awnedness in wheat. As with some other characters, therefore, the inheritance of awnedness in wheat has been found to be simple in some crosses and in others very complex.

Quisenberry and Clark (*81*) proved the above inheritance from a cross between Sonora and Quality, two awnleted wheats (classes 3− and 3+), from which a complete range of segregation was obtained in F_2 from awnless to awned. In the F_3 generation, true-breeding awnless (class 1) and awned (class 5) strains were obtained, as well as pure awnleted strains like both parents. There was also a wide range of segregating groups. It was assumed that, with the two major dominant factors, *A* and *B*, for awnlessness, Sonora contains the factors *aaBB* and Quality contains the factors *AAbb*, whereas awnless segregates are *AABB* and awned ones are *aabb*.

If in some other varieties or crosses the awned condition is dominant, it should be possible to prove the inheritance by crossing two awned varieties differing in the possession of major factors for awnedness and by obtaining true-breeding awnleted or awnless strains and a wide range of segregating groups. This is suggestive of an unsolved genetic problem for awnedness, and there are many others, such as the cumulative transgressive segregation which can be obtained from one cross to another, and the inheritance of the true-breeding api-

[10] Clark et al. (*19*), further presented results from the triangle crosses between the Bobs, Hard Federation, and Propo varieties. In crosses between the awnless Bobs and Hard Federation (class 1) parents with the awned Propo (class 5) parent, imperfect dominance of awnlessness was shown, as the F_1 (class 2) approached nearer the awnless than the awned parent. The F_2 and F_3 plants were separated into five classes. By combining the number of F_2 plants in classes 1 and 2 and comparing them with the combined number in classes 3, 4, and 5, the corrected F_2 results for both crosses were statistically close to a two-factor or 9 : 7 genetic ratio. The cross, Bobs × Propo, was less complicated in F_3 than the Hard Federation × Propo. There was also found to be segregation for awnedness in the Bobs × Hard Federation, or awnless × awnless, into classes 1 and 2 in the ratio of 13 : 3. A genetic interpretation of the results of the Bobs × Propo was made on the basis of two major (*AA* and *BB*) factor pairs, and for the Bobs × Hard Federation on two minor (*CC* and *DD*) factor pairs. The corrected F_2 ratio for the five classes in the Bobs × Propo was 1 : 8 : 4 : 2 : 1. This has been repeatedly shown in different crosses to be the basic two-factor phenotypic ratio for the inheritance of awnedness in crosses between awnless × awned wheats. Some crosses are more complicated.

cally awnleted (class 2) and short-awned (class 4) strains, rarely but sometimes obtained in certain wheat crosses.

INHERITANCE OF QUANTITATIVE CHARACTERS

With the progress of genetic analysis it early became clear that the individual effects of a large number of factors are not apparent. Individually the action of such genes is small, and it is only in a large population that their influence can be shown. This is the evidence upon which the multiple-factor theory was founded. In this category belong many of the quantitative or intergrading characters. In genetic studies of quantitative characters, therefore, the plants are classified in numerical or percentage frequencies rather than in classes or groups. The inheritance usually is more complicated and difficult to interpret genetically than the inheritance of qualitative characters.

Important quantitative characters in wheat are time of maturity and winter hardiness. A brief summary of genetic studies with these two is given. Other quantitative characters would include many factors governing resistance to disease, quality of grain, height of plant, strength of straw, and productivity. Yield is largely controlled by quantitative factors.

Maturity (Early or Late)

The relative dates at which wheat varieties head and ripen when sown at the normal time in regions where they are adapted are very important. Early maturity usually is considered one of the most important characters for improvement under conditions of drought or in regions liable to early fall frosts. Under favorable conditions, however, earliness seldom is considered an advantage, and when obtained it is usually accompanied by reduced yield. The date-of-heading period usually is less affected by environmental conditions than the ripening period, and it has been considered by most workers as the best measure to use in a study of maturity inheritance.

The term "fruiting period" is a designation for the number of days from heading to ripening and was first used by Carleton in 1905. He later (*12, p. 275*) emphasized its importance "as the most critical period in the life of the crop" and called attention to "the correlations existing between the length of this period and certain other characteristics of the crop, as yield and protein content."

Farrer (*32*) early reported that the heading period in F_1 hybrids is intermediate to that of the parents and that there was no difference in this respect in reciprocal crosses. Other workers such as Bryan and Pressley (*11*), in crosses between Sonora and Turkey, found the F_1 intermediate in time of heading to the parents, but the F_2 majority inclined toward the late parent. Florell (*34*), however, from results with the Sunset × Marquis cross, found early heading dominant, and in F_2 "there was a distinct heaping up of the population into a large early and a small late group in the proportion of 3.07 to 0.93." He concluded that "it is possible to determine progeny rows homozygous for earliness in F_3 and subsequent generations of hybrids by the time required for them to pass through the heading stage." Clark (*13*) in Kota × Hard Federation crosses also found earliness partly dominant to lateness.

Thompson (*101*) used dates of ripening as a basis for inheritance studies of maturity in several crosses. In some, the F_1 generation was near the mean of the later parent. This apparent dominance of late ripening in the F_1 generation was explained as due to heterosis or hybrid vigor, the bigger, more vigorous plant taking longer to develop, and other complicated results as due to multiple factors.

In further work by the writer (*20*) with Marquis × Hard Federation and reciprocal crosses, maturity studies were made from dates of heading, dates of ripening, and the number of days between these dates (heading to ripening), or the fruiting period. In F_2 early heading appeared partially dominant, although there were no large early and no small late groups. The time of heading of the hybrids was significantly more variable than that of either parent,[11] but the time of ripening of the hybrids was nearly intermediate between the parents and not significantly more variable.[12] The average fruiting period of the hybrids also was intermediate to the fruiting periods of each parent.[13]

These studies illustrate how complicated the inheritance of a quantitative character such as maturity may be in some crosses, while in others it may be very simple.

Winter Hardiness

Winter wheats vary greatly in their ability to resist cold and to survive the winter. Many reports have been published on the relative resistance of varieties of wheat to killing by cold, but few genetic data are available on the inheritance of this character.

Relative cold resistance often is rather difficult to determine in the field. The winter may be mild and little or no killing will occur, or a severe winter may wipe out an entire experiment. Salmon (*85*) points out that winter-killing may be due to any or all of the following four causes: (1) Heaving, (2) smothering, (3) physiological drought, and (4) direct effect of low temperature on plant tissues.

Newton (*72*) attempted to find some chemical or physical measure that would give an indication of resistance to cold. He concluded that the hardier the variety the lower the moisture content of the leaves, and that in hardened-off leaves this moisture is held under a greater force. He found that the volume of press juice per 100 grams of hardened tissue was inversely proportional to hardiness. The quantity of hydrophylic, or water-attracting, colloids in the press juice was directly proportional to hardiness. Martin (*65*) conducted experiments similar to those of Newton and concluded that none of these chemical or physical measures offered a more accurate test of resistance to cold than did a careful field study. Martin pointed out that considerable care must be exercised in properly hardening off the material before subjecting it to low temperatures.

[11] No earlier heading strains than Hard Federation were produced, but transgressive segregation for lateness of heading was found, as F_3 strains were obtained which were significantly later in heading than Marquis.

[12] Strains having a variability no greater than that of either parent were obtained in the F_3 generation, some of which averaged as late or later in ripening than the Marquis parent.

[13] Strains with short and long fruiting periods were observed, the means of which differed by as much as 8 days. One F_3 strain was obtained which had a significantly shorter fruiting period than that of Marquis at two localities, but no hybrids were found to have a longer fruiting period than that of Hard Federation.

Nilsson-Leissner (*75*), reviewing a book by Åkerman, points out that Åkerman suggests the use of artificial refrigeration in the study of resistance to cold and that by using this method he was able to show transgressive segregation in some hybrid material. Walter (*106, pp. 110–121*) in recent studies has shown that several things may tend to prevent the recovery of water from living tissue, and he and other German workers hold that the tissue must be killed first before the expression of the juice, in laboratory studies of hardiness.

Nilsson-Ehle (*74*) crossed two varieties of intermediate hardiness and obtained some lines that were more hardy and others that were less hardy than the parents. He concluded that winter resistance behaved like other quantitative characters, being controlled by several genetic factors.

From a Turkey × Odessa cross, Hayes and Garber (*47*) reported the development of new wheats more cold resistant than the Odessa parent. One of the wheats, Minhardi, was later determined (*24*) to be the most hardy winter wheat tested in the United States and Canada.

Martin (*65*) studied F_3 lines of Kanred × Minhardi for hardiness, but was unable to determine the number of genetic factors involved, although most of the strains were intermediate between the parents in resistance to cold. Hayes and Aamodt (*46*) reported a study on the inheritance of cold resistance and growth habit in crosses of Marquis (spring) and Minhardi and Minturki (winter) wheats. They agreed with Nilsson-Ehle that cold resistance is inherited in the same manner as other quantitative characters, although they, likewise, were unable to determine the number of factors involved. Winter strains as hardy as Minturki were produced.

Summarizing 10 years' work on breeding for winter hardiness, Quisenberry and Clark (*80*) concluded that the winter-hardiness character is very complex and is greatly influenced by environment. From a large number of crosses between winter wheats of varying degrees of hardiness, segregates were obtained which were as hardy as, and in some cases hardier than, the hardy parents, although most of the strains were intermediate.

INHERITANCE OF DISEASE REACTIONS

The presence and importance of disease resistance in wheat is well known. Marked progress has been made in breeding wheat for disease resistance in recent years. The application of a knowledge of genetics, plant pathology, and plant physiology has furnished a scientific basis for the practical breeder in developing disease-resistant varieties of agronomic value. Many fungous diseases contain numerous physiologic forms. Two of the most destructive of these diseases are stem rust and bunt. Aamodt (*2*) has recently summarized the relationship between physiologic forms and breeding for resistance, and Dickson (*31*) the physiological nature of immunity in plants. Only some of the genetic results with the different reactions established for the two diseases, stem rust and bunt, will be summarized here. Other destructive diseases are leaf and stripe rust, loose smut, mildew, scab, black chaff, foot rots, etc.

Stem Rust Reactions

In the United States heavy losses from stem rust (*Puccinia graminis tritici* Eriks. and Henn.) in 1904, 1916, and 1935 brought a demand for new varieties of hard red spring and durum wheats resistant to or immune from the disease. The 1935 epidemic resulted in losses estimated at $100,000,000 in North Dakota alone. Breeding work with spring wheat for rust resistance was started by the United States Department of Agriculture following the great rust epidemic of 1904.

During the early years, breeding for resistance to stem rust was difficult because only durum wheat and emmer as resistant parents were available for crossing. Crosses between either of these species and susceptible common wheats involved sterility and usually a linkage of resistance with undesirable durum or emmer characters. With the discovery of resistance in Kota (*105*), a common hard red spring wheat, in 1919, these difficulties were partially solved.

This resistance, however, was not sufficient to guard against all possibility of loss. The F_1 inheritance of resistance in Kota (*13*), common wheat, and also the resistance in Iumillo and Acme (*48*), durum wheats, was recessive but nevertheless complicated because relatively few, and in some cases none, of the hybrid plants in F_2 or later generations were as resistant as the resistant parents.

The discovery of physiologic forms of rust has contributed to an understanding of the inheritance of resistance. At first it was felt necessary to breed for resistance to certain forms, but Aamodt (*1, 2*) showed that a single genetic factor for seedling immunity in Kanred governed the reaction to 11, and later to more, of the older established forms. More recently it has been shown, by different workers in both the United States and Canada, that the behavior of the host in the seedling stage to the pathogen, or disease-producing organism, is not necessarily correlated with the corresponding behavior of the host in the mature stage. It has become evident, therefore, that in practical breeding for resistance, only the behavior of the mature plants is of importance. The inheritance of this mature plant reaction only, therefore, will be reviewed. It has been found that the mature plants act more or less as a unit against groups of rust forms. With some hosts, as emmer, the action is unitlike against all forms.

The white spring emmer grown commercially in the United States has been nearly immune from stem rust for at least 50 years. From early crosses with common wheat, Hayes, Parker, and Kurtzweil (*48*) predicted that the transfer of this near immunity from emmer to common wheat was possible. However, McFadden of South Dakota (*64*) was the first to develop from this wide cross hard red spring wheats having the rust reaction of the emmer parents. He produced the two wheats, Hope and H–44, from a cross between Marquis wheat and Yaroslav emmer. In the mature plant stage these wheats have been found nearly immune from all the physiologic forms of stem rust.

This was at once recognized as important in itself, but of even greater importance was the fact that this near-immune reaction was a new character in common hard red spring wheat. No sterility is involved in further crosses with these and other common wheats, and a large number of nearly rust-free plants and strains have been obtained in hybrid populations.

Clark and Ausemus (*17*) first pointed out that in the F_1 and F_2 generations of crosses with Hope, its near immunity was inherited as a dominant character, whereas resistance, as in Kota, was inherited as a recessive character, the dominance in both cases being imperfect or incomplete. The F_1 plants of Hope crosses had only a trace of rust. In the F_2 generation there was a piling up or a preponderance of the plants toward the zero or rust-free end of the distribution.

In 1928, at the annual meeting of the American Society of Agronomy, Clark and Ausemus [14] presented F_3 data showing that when Hope was crossed with Marquis or Reliance, true-breeding strains were obtained, classified as near immune, resistant, and susceptible, together with four types of segregation. The results were explained genetically on a two-factor basis. In a Hope-Ceres cross only a single-factor difference was shown.

During or since that time Goulden, Neatby, and Welsh (*43*) found that in a cross of H–44 and Marquis the mature-plant reaction in the field was controlled by a single pair of genetic factors. Neatby and Goulden (*70*) in a later study with a Hope-Marquis cross concluded that two complementary factors were involved. In 1932 Clark and Humphrey (*21*) showed that the inheritance in the H–44 × Ceres cross is similar to that of the Hope × Marquis and Hope × Reliance crosses previously reported, proving the two-factor inheritance.[15]

In other studies by the writer and his associates of crosses of Hope and H–44 with more susceptible varieties, Supreme, Power, and Reward, the inheritance was found to be more complicated. The data from these crosses show that there is more than one factor for susceptibility, and that these factors may differ in amount of effect. In all crosses of Hope and H–44 with resistant and susceptible varieties that have been studied by the writer, there is little evidence of more than one dominant factor for near immunity, as the single-factor segregation for this reaction usually is definite. In further studies by Clark and Smith (*29*) no additional minor or modifying factors could be directly established from the results of three crosses. There is circumstantial evidence, however, to show that in most crosses, additional minor factors for susceptibility are operating, making it difficult to obtain in hybrid strains as complete freedom from rust as in the Hope and H–44 parents.

Among the durum wheats, Iumillo, Pentad, and Acme are the most resistant varieties. In the United States they usually show more rust than does Hope, as they have a trace or more of rust, but they are seldom if ever seriously injured. Some workers have thought that the rust reaction of these durums is the same as that of Hope. That the resistance of Iumillo and Acme is inherited as a recessive character in crosses with susceptible common wheats was early shown by Hayes, Parker, and Kurtzweil (*48*). Smith and Clark (*92*) have shown recently that the resistance of Pentad also is recessive in

[14] CLARK, J. A., and AUSEMUS, E. R. INHERITANCE OF IMMUNITY FROM BLACK STEM RUST, YIELD, AND PROTEIN CONTENT IN HOPE WHEAT CROSSES WITH SUSCEPTIBLE AND RESISTANT VARIETIES. p. S. Washington, D. C. 1928 [Mimeographed.]

[15] The true-breeding and segregating F_3 strains are shown by their distribution in 10-percent frequency classes, by their average rust infection, and by their standard deviation computed from the frequencies. A good agreement was obtained for a given genetic interpretation in which it was assumed that Hope had a dominant inhibiting factor for near immunity, that Marquis and Reliance had a major dominant factor for susceptibility, that H–44 carried both of these dominant factors, and that the resistant Ceres was represented by the double recessives. It was recognized that any genetic interpretations would meet with some difficulties because the inherited reactions were affected by environmental influences on both the host plant and the pathogen. The hypothesis given was also in agreement with the findings of Goulden, Neatby, and Welsh and with those of Neatby and Goulden previously cited.

crosses with Akrona, a susceptible durum variety.[16] In studies by Glenn S. Smith made in 1932 at Langdon, N. Dak., from a Vernal emmer × Mindum durum wheat cross, some F_3 results suggest the possible presence in emmer of three dominant factors for near immunity. Following a series of backcrosses to eliminate the objectionable emmer characters, it appears now entirely possible to obtain durum wheats carrying one or two additional factors for near immunity, obtained from emmer.

The three differently inherited reactions now known—near immune, resistant, and susceptible—have been defined by the writer (*15*). If a further reaction or a new character for complete immunity could be produced from crosses with the new species, *Triticum timopheevi*, or some other species or genus, further genetic studies might serve to supplement the valuable findings already available.

However, it is now the opportunity of the breeder to make use of the inheritance studies that have been made and the material available and combine in an otherwise desirable variety the resistant and near-immune reactions now known, or as many near-immune factors as are necessary to insure freedom from rust injury under any environment.

Bunt Reactions

Bunt, or stinking smut, long has been a serious disease of wheat in the United States and particularly in the Pacific Northwest. In that section the many physiologic forms of bunt are an added difficult problem for the wheat breeder. Rodenhiser and Stakman (*83*), Gaines (*40*), Bressman (*9*), and others have studied and reviewed the physiologic specialization work with bunt, and Rodenhiser and Holton now have collections of all known forms.

The pioneer work in breeding wheat for resistance to bunt, or stinking smut [*Tilletia tritici* (Bjerk.) Wint. or *T. levis* (Kuehn)], was done in Australia by Farrer and in the United States by Gaines of Washington. Farrer (*33*) in 1901 reported his first attempts to bring about bunt resistance in wheat by hybridization. He made no attempt to observe segregation or establish Mendelian ratios. Gaines (*38*) began his investigations, including the genetics of resistance, in 1915, and in 1923 (*39*) he described his extensive results. He grouped varieties into four classes—susceptible, intermediate, resistant, and immune. When resistant varieties were crossed with susceptible ones, susceptibility was dominant, with only about 2 percent of the progeny as resistant as the resistant parent. When susceptible varieties were crossed with the immune ones—Martin and Hussar—there seemed to be a dominance of resistant plants. More than half of the hybrids in the third generation produced less than 5 percent of bunted heads, whereas about 20 percent were bunt-free.

Gaines believed that the results indicated that immunity or resistance to bunt is due to the combined effect of several factors. When all are present, as in immune varieties, they produce apparent dominance, but a lesser number gives the recessive effect. Briggs (*10*),

[16] That the factor for near immunity obtained in Hope from emmer is not the same as that causing resistance in Marquillo obtained from Iumillo durum is indicated by transgressive segregation for susceptibility shown in F_3 by Ausemus (*3*) in a Hope × Marquillo cross. Susceptible F_3 plants from a Hope × Thatcher cross also have been obtained under greenhouse experiments by Clark and Humphrey. (Unpublished data.) These susceptible plants and strains could not have been obtained if the factors had been the same.

however, found that the Martin variety had one dominant factor for near immunity and that Hussar had two. In a further excellent series of papers, Briggs has shown the inheritance of bunt reaction in different crosses to be rather simple, due to one or two genetic factor differences. He worked principally with only one form of bunt and with the near-immune reaction possessed by the Martin and Hussar varieties.

The strong resistance of Hope wheat to bunt was studied by Clark, Quisenberry, and Powers (*28*), in crosses involving the weaker resistance of Marquis and different degrees of susceptibility in Ceres and Hard Federation. Three crosses were studied on a collection of bunt (*Tilletia levis*) from Montana. The results indicated that several factors were involved but that the stronger the resistance in the parents the less complicated is the inheritance.

The near-immune reaction to some strains of bunt possessed by Hussar has been transferred to hard red spring wheat in a Komar × Hussar cross by Smith (*93*). From a cross of Hussar, a hard red winter wheat, and Hard Federation, a white spring wheat, another nearly immune hard red spring wheat (N. No. 1018, C. I. No. 11442) has been developed by Florell and Bayles.[17] Both of these strains have been crossed with susceptible varieties, and the F_1 plants were found by the writer (*15*) to be bunt-free, proving dominance of near immunity. In F_2 and F_3 studies conducted by the writer and H. A. Rodenhiser, these crosses have shown a single-factor segregation.[24] This is sharply in contrast to the inheritance of resistance from such varieties as Hope, Marquis, Ridit, Oro, Turkey, and Florence crossed on susceptible varieties, in which the F_1 plants are susceptible.

With bunt, therefore, as with rust, we have the three differently inherited reactions—near immunity, resistance, and susceptibility. It is now the further opportunity of the wheat breeder to combine in a single variety the near-immune reactions for both the stem rust and bunt diseases.

INHERITANCE OF QUALITY CHARACTERS

Quality in wheat is complex and involves many characters. In milling and baking experiments as many as 20 properties are sometimes studied. In addition to bread making, there are characters or factors for quality in pastry, crackers, cake, etc., among the soft wheats, and factors for quantity in semolina and macaroni among the durums. The inheritance of only a few of these characters has been studied—principally crude-protein content and baking strength.

Protein Content

In some wheat-producing sections, such as the drier sections of Montana, the crude-protein content is often more important economically than any other single quality factor. Premiums are paid to farmers for high-protein wheat, varying with the quality of their crop each year and with the quality of high-protein wheat available. The value of flour for bread-making generally is improved by increasing the protein content, and millers desire some high-protein wheat for blending.

Lyon (*63*) and Roberts (*82*) studied the variation and differences of crude-protein content in individual plants and pure-line strains of

[17] Unpublished data.

a variety. Clark and his associates (*14, 19, 20, 26*) have studied the segregation and inheritance of crude protein content in hybrids of several crosses, in Montana under conditions favorable for high-protein content, and in California under conditions that favor low-protein wheat. From the studies it was concluded that there is segregation for crude-protein content in wheat hybrids similar to that for other quantitative characters. The data indicate that the inheritance of crude-protein content is as complex as that of yield and that environment is fully as important in determining the result in one case as in the other. The two characters, protein content and yield, are frequently but not always negatively associated. Kernel texture and the time of maturity of plants are also important factors affecting protein content. It was not possible to show any definite genetic segregation.[18]

These inheritance studies indicate that the total amount of crude protein per acre, however, may be increased through improvement in yield with maintenance of the crude-protein content of the highest parent. It appears that in some cases at least, a material increase in the crude-protein content of the grain of an otherwise desirable variety can be obtained by crossing with a high-protein parent, but only with sacrifice in yield.

Baking Strength

Baking strength, or the ability of gluten to stretch without breaking down so that it will make a large loaf, was early studied by Saunders (*87, 88*) who concluded that its inheritance is very complex and probably depends on a number of Mendelian factors. Other early workers, Biffen (*7*) and Howard and Howard (*51*), reached similar conclusions, although they showed that texture, or hardness and softness of the endosperm, behaved as a simple Mendelian character in some crosses.

Many methods, including the viscosity test used by the writer (*13*), have been studied with a view to finding one that would determine baking strength, or quality of the gluten, and that at the same time could be used for making inheritance studies, but with little success. Any successful method must involve the use of small samples without grinding flour or baking bread.

Recently Worzella (*109*), using the wheat-meal fermentation time test, studied progenies of a cross between Trumbull, a weak-gluten parent, and Michikof, a strong-gluten parent. The gluten strength of the F_1 plants (F_2 endosperm) was intermediate to the parents. In F_2 the hybrid plants also were intermediate, and in F_3, families as weak as Trumbull and as strong as Michikof were obtained. Some strains bred true while others showed different degrees of segregation. A genetic interpretation was given on the basis of three major independent factor pairs. There was close agreement between the observed and calculated numbers on a 1:6:15:20:15:6:1 basis. It was concluded that gluten strength is a hereditary quantitative character and is apparently accurately measured by the fermentation test.

In a recent paper Parker (*77*) has reviewed in more detail the breeding work with wheat for improved quality.

[18] The data show that some high-protein F_3 strains were obtained from plant selections made in the F_2 on the basis of high crude protein content, but that such F_3 selections were not always higher in content than others from an F_2 plant of lower protein content. No plus transgressive segregations were found in protein content.

WHEAT SPECIES, CYTOLOGY, AND CROSSABILITY

In 1932, at the sixth international congress of genetics at Cornell University, 35 different papers were presented on the relation of cytology to genetics. With wheat and other genera the chromosome numbers, crossability, chromosome pairing, fertility, and plant morphology are being studied by both cytologists and geneticists, the two often cooperating. Many wheat breeders have made interspecific and intergeneric crosses (that is, crosses between species and between genera) to study the possibilities of such crosses for practical breeding values. A genetic analysis of most of these crosses has been impossible because of the lack of fertility of the hybrids. Practical breeding results have been obtained, however, in the Marquillo and Hope varieties, for their stem rust reactions.

Botanically, wheat belongs to the grass family, Poaceae, and the genus *Triticum*. The following species (table 1) have been recognized by different workers, arranged in order of their haploid chromosome numbers; that is, the number in the germ cells, which is half that in the body or somatic cells. In recent years the species of wheat have been reclassified partly upon the basis of chromosome numbers.

TABLE 1.—*Triticum species* [1]

Diploid series (7 chromosomes)	Tetraploid series (14 chromosomes)	Hexaploid series (21 chromosomes)
T. aegilopoides Bal.	*T. dicoccoides* Körn	*T. spelta* L.
T. monococcum L.	*T. dicoccum* Schubl.	*T. vulgare* Vill.
T. thaoudar Reu.	*T. durum* Desf.	*T. compactum* Host.
	T. turgidum L.	*T. sphaerococcum* Perc.
	T. polonicum L.	*T. macha* Decap.
	T. persicum Vav.	*T. vavilovi* Jackub [2]
	T. orientale Perc.	
	T. pyramidale Perc	
	T. timopheevi Zhuk	

[1] Common names of the older species are given below, new species have no common names as yet.
[2] The chromosome number is not certain.

The earliest reliable chromosome counts were reported by Sakamura (*84*) in 1918 on eight species. These counts have since been verified by Sax (*89*), Kihara (*56*, *57*, *58*), Watkins (*108*), and others and the chromosome numbers of additional species established. The somatic chromosome numbers of these groups are 14, 28, and 42. The first eight species studied by Sakamura were common wheat, *T. vulgare;* club wheat, *T. compactum;* spelt, *T. spelta;* durum wheat, *T. durum;* poulard wheat, *T. turgidum;* emmer, *T. dicoccum;* Polish wheat, *T. polonicum;* and einkorn, *T. monococcum.*

In the tetraploid series listed in table 1 (14 haploid chromosomes), there is included a comparatively new species, *T. timopheevi* Zhuk., which was first described by P. M. Zhukovsky as a variety of wild emmer, *T. dicoccoides* Körn., after the chromosome number determined in the somatic cells proved to be 28. The "genom"-analytical [19] studies of Kihara (*59*) have shown that *T. timopheevi* possesses a genom not present in other tetraploid species and has not been detected in the diploid or hexaploid wheat species or in *Aegilops*.

[19] A "genom" (coined word for gene + chromosome) is the basic unit of chromosomes for any plant. In the case of wheat, this unit is 7.

Interspecific Crosses

Crosses between any two species with the same chromosome numbers are easily made, with the exception of *T. timopheevi*. The F_1 hybrids usually are self-fertile, and in most F_2 populations normal Mendelian segregation occurs.

Crosses between species with different chromosome numbers are less easily made. Thompson (*102*) has studied the cytological causes. Pentaploid (14×21) hybrids are partly self-fertile. Triploid (7×14) and tetraploid (7×21) hybrids are self-sterile. Most of the F_1 hybrids involving *T. timopheevi* crosses are self-sterile.

The *T. durum* × *T. vulgare* (14×21) crosses are among the least difficult to produce. Oehler (*76*) has shown that up to 40 percent of the flowers pollinated produce kernels. The F_1 is intermediate between the parents and partly sterile. In F_2, segregation into a great many types occurs, with varying degrees of fertility. Several examples are on record of results of practical value having been obtained from such crosses. The Marquillo variety was developed in cooperative experiments at the Minnesota Agricultural Experiment Station from a Marquis (*T. vulgare*) × Iumillo (*T. durum*) cross. Marquillo has some of the stem rust resistance of the Iumillo parent. This resistance has been further transmitted through a double cross, Marquis-Iumillo × Kanred-Marquis, in the production of the Thatcher variety.

Crosses of *T. dicoccum* × *T. vulgare* are somewhat more difficult to obtain. The F_1 hybrids resemble *T. dicoccum* and are nearly self-sterile. In F_2 there is almost a complete range from sterile to fertile plants, and the number of segregating types is greater than in the case of *T. durum* × *T. vulgare* crosses. The successful transfer from emmer of the near-immune reaction from stem rust was accomplished by McFadden (*64*) in the cross Yaroslav (emmer-*T. dicoccum*) × Marquis (*T. vulgare*). The Hope and H-44 wheats thus produced have become widely used as parents in wheat breeding.

Crosses of einkorn, *T. monococcum*, with wheats having 14 and 21 haploid chromosomes are even more difficult. With *T. monococcum* × *T. durum* (7×14) less than 10 percent of the flowers pollinated set seed, and with *T. vulgare* (7×21) only 3 to 4 percent. These interspecific F_1 hybrids usually are self-sterile, but they may be successfully backcrossed with the parents or crossed with other varieties and a small percentage of viable seeds obtained. These in turn produce plants, some of which show increased fertility.

Crosses of *T. timopheevi* with each of the diploid (7), tetraploid (14), and hexaploid (21) species so far all appear difficult.[20] Because of its complete freedom from the rusts, smuts, mildew, and other diseases, *T. timopheevi* is a desirable parent if its disease reactions can be transferred to the *T. durum* and *T. vulgare* species. From *T. timopheevi*, for instance, we might obtain new characters, such as

[20] The results of Kihara (*59*) in Japan showing the high self-sterility of the F_1 suggests that the new wheat must be quite different from the other tetraploid species. Katayama (*55*), in his experiments on grain set and germination, found that crossed kernels could be obtained with relative ease in the *T. timopheevi* × *T. durum* and reciprocal crosses, and the seed germinated 94 percent, but in *T. timopheevi* × *T. vulgare* crosses, seeds were obtained only when *T. timopheevi* was used as the female, and these did not germinate. These results differ somewhat from those of such wheat breeders as Sando, Shands, Waldron, McFadden, G. Smith, and others in this country who have made many different crosses, using *T. timopheevi* as one parent. No self-fertile hybrids with durum have been obtained, but Waldron had successful germination on an F_1 seed with *T. vulgare*. The plant was self-sterile, however, and all backcrosses were failures. Likewise, Sando has successfully produced a number of F_1 hybrids between *T. timopheevi* and *T. vulgare*. The F_1 hybrids were self-sterile but a small percentage of seeds was obtained by backcrossing on the F_1. The resulting plants showed partial self-fertility.

complete immunity from stem rust, in which the disease organism cannot enter the host plant, in contrast to the near-immune reaction of Hope wheat, obtained from emmer, in which the disease organism enters the host but cannot usually develop further. Spikes and kernels of *T. timopheevi* are shown in figure 34.

FIGURE 34.—Spikes and kernels of *Triticum timopheevi*.

Intergeneric Crosses

Crosses between species of *Triticum* and species of *Hordeum* (barley), *Secale* (rye), *Aegilops* (a wild wheat), *Agropyron* (couch grass), and *Haynaldia* offer an even more difficult but a further field for improvement in wheat. More incompatability in crossing and greater sterility is encountered, but some successes have been reported. The object is to obtain new characters, such as the winter hardiness of rye, drought resistance of *Aegilops*, etc.

All species of barley have seven chromosomes. The wheat varieties, Bobs and Canberra, produced by the late William Farrer of Australia, were first reputed to be the result of wheat-barley or *Triticum Hordeum* crosses, but this was later retracted. Many attempts have since been made to produce hybrids of wheat and barley but without success. However, Gordon and Raw (*42*) in Australia recently have reported a combination of these genera. They found that occasional kernels were produced from attempted crosses and that the F_1 progeny of these were like

the ovule parent in species character and chromosome number, but they exhibited no sterility. However, chromosome disturbance of some kind evidently took place, since segregation of characters was observed in progeny plants of the segregating generations.

Secale or rye (7 chromosomes) can be crossed with most species of wheat, but some crosses are more difficult to obtain than others. The ease with which wheat may be crossed with rye depends upon the species and variety of wheat used. Florell (*35*) reported the 21-chromosome varieties were fertilized quite easily with rye pollen, while the 14-chromosome varieties were fertilized with difficulty or not at all. Gaines and Stevenson (*41*) and also Nina Meister and Tjumjakoff (*68*) have reported the making of the reciprocal or rye-wheat crosses (that is, using rye as the female and wheat as the male), previously considered to be impossible. Gaines' and Stevenson's hybrids were all ryelike but segregated for other plant characters, while Nina Meister's and Tjumjakoff's hybrids were mostly wheatlike, as with wheat-rye crosses.

Wheat breeders have been backcrossing winter wheat and rye hybrids with winter wheat to increase winter hardiness. Bleier (*8*), Florell (*35*), and others have reviewed these experiments and studied the transmission of rye characters to wheat. As many workers have reported low percentages of kernels obtained from wheat and rye crosses, and others report high percentages, Backhouse (*4*) and more recently Taylor and Quisenberry (*99*) studied the inheritance of crossability and concluded that it is a heritable character that can be transferred to wheat segregates. The almost total self-sterility of the F_1 wheat-rye hybrids has been shown by Jesenko (*53*) and Leighty and Tayor (*61*). Florell (*35*) showed fertility was increased by back-crossing with the parent wheat, and progeny plants became more wheatlike. Parent types were recovered in the second backcross, second and third generations. A wheatlike, nearly homozygous, red-kerneled progeny and an apparently homozygous hairy-necked progeny were obtained from a Hybrid 128 × Rosen cross, indicating the possibility of producing constant wheat-rye strains.

Meister (*67*) reported in natural wheat-rye hybrids, segregation for frost resistance and the production of true-breeding strains of winter wheats of increased hardiness. He also has distributed a 28-chromosome strain.[21]

Tschermak (*103*) after 30 years' trial claims to have succeeded in producing a constant wheatlike hairy-neck wheat and rye hybrid, having 21 chromosomes. Most likely this is a case of substitution of a pair of wheat chromosomes or parts of them by a pair of rye chromosomes.

The genus *Aegilops* offers the possibility of increasing drought resistance in wheat. It is a polymorphic genus of grass, that is, a genus with many forms, indigenous to the countries bordering the Mediterranean. It is represented by three groups of species having 7, 14,

[21] Taylor (*98*) reported on the constancy of the hairy-neck character in three selfed hairy-neck wheatlike selections from wheat-rye hybrids, continued for eight generations. Constancy was not obtained. The cytologic and genetic studies of Florell (*36*) indicated that rye factors apparently may be added to the wheat complement as whole rye chromosomes, but the results of subsequent experiments (unpublished data) show that these tend to become eliminated.

and 21 haploid chromosomes, respectively. Sando and others have found, with only a few exceptions, that all species when crossed with wheat species produce self-sterile F_1 hybrid plants. Cytological studies have shown that most of the self-fertile hybrids are amphidiploid, that is, there is a complete doubling of chromosomes, although in a few this full doubling was not effected. No wheats of economic importance have as yet been developed from such crosses.

The genus *Agropyron* has been used in crosses with wheat by Russian breeders to produce a perennial wheat. The possible value of such a wheat is problematical. *Agropyron* is represented by species having 7, 14, 21, 28, and 35 haploid chromosomes. Vavilov[22] has reported:

> The work of the Omsk, Saratov, and other stations has proved that we have species of couch grass (*Agropyron*), such as *Agropyron elongatum* and *A. junceum*, that produce fertile hybrids when crossed with ordinary or durum wheat. The recent work of Prof. Vakar has shown that *Agropyron elongatum* has 21 chromosomes homologous with ordinary wheat chromosomes and, in addition, 14 specific *Agropyron* chromosomes which pair among themselves (process of autosyndesis), when these two genera are crossed. This work is only in its beginning. Theoretically, it is not very easy to get the ideal combination of all good wheat characters and all the most desirable characters from couch grass, but already good, new forage types are in the hands of the plant breeders.

Haynaldia is represented by several species, one of which (*villosa*), with seven haploid chromosomes, has been used by Sando (*85a*) in crosses with wheat. All but one of the F_1 hybrids resulting from Sando's crosses of *Haynaldia* with diploid, tetraploid, and hexaploid species of *Triticum* are self-sterile. A few seeds were produced by the F_1 hybrids of the cross *T. turgidum* × *T. villosa.* The fertility of the plants increased in subsequent generations until almost complete fertility was obtained. A constant fertile hybrid between *T. turgidum* × *T. villosa* (*Haynaldia*) also was obtained by Tschermak (*104*).

STATISTICAL METHODS

The employment and value of statistical methods in wheat breeding and genetics must be emphasized. After accurately recording and assembling data, biometry is an indispensable aid for analyzing the results for both the practical breeder and the geneticist. The agronomist and pathologist, too, have need for the use of statistical methods to obtain a final summary of the results of all lines of work involving variation, including variety testing, and forms of a fungus disease. The proper employment of the many different statistical methods insures a conservative, reliable, and pleasing conclusion to one's work.

IMPROVEMENT IN PRESENT WHEAT-BREEDING METHODS

One of the objects of this cooperative survey of wheat improvement was to receive suggestions from the many workers for improving present wheat-breeding methods. For the United States, the compilers of the report for some of the States made the following suggestions:

[22] From a memorandum to J. A. Clark.

CALIFORNIA—*B. A. Madson, F. N. Briggs.*

More use of the backcross.

GEORGIA—*R. P. Bledsoe, S. J. Hadden.*

Suggest more extensive cooperation between and among the various State agricultural experiment stations, especially in the way of experiments having a regional application. Also suggest exchanges of material for testing.

IDAHO—*C. A. Michels.*

Make a large number of crosses, and handle by bulked method until population approaches homozygosity. Then make head selections.

ILLINOIS—*O. T. Bonnett.*

(1) The production of a large number of hybrid combinations and the choice of the best combinations for intensive selection; (2) a greater use of the backcross, three-way, and doublecross in producing hybrid combinations; (3) a more thorough evaluation of parent varieties from a physiological standpoint; (4) use of bulk hybrid method.

INDIANA—*A. T. Wiancko, G. H. Cutler.*

(1) The fermentation time test of whole wheat developed at this station gives promise of solving quality testing of small plant breeding samples; (2) the granulation test of whole wheat meal also holds promise as a measure of fineness of flour a given wheat may make.

KANSAS—*H. H. Laude, John H. Parker.*

Continued emphasis on yield, as influenced by ancillary characters such as winter-hardiness, earliness, strong straw, tillering, size of head, size of kernel, resistance to diseases and insects.

MICHIGAN—*H. M. Brown.*

There is a need for equipment and procedure which will quickly and accurately make flour from 25 to 100 grams of grain and then test that flour (which should be comparable to standard flour in fineness) for quality.

MINNESOTA—*H. K. Hayes, R. H. Bamberg.*

Our studies have emphasized the necessity of learning the value of individual characteristics of varieties and definite genetic plan for combining all desirable characters in one variety, based on mode of inheritance of individual characters.

MISSOURI—*E. M. Brown.*

A more detailed study of yield factors to serve as guide in hybridization.

NEBRASKA—*T. A. Kiesselbach.*

Use disease and insect epidemics, control hardiness tests, and mechanical devices for measuring strength of straw and shatter resistance, in connection with the selection and testing, either within commercial varieties or segregating populations.

NEW YORK—*H. H. Love.*

It seems to me that much valuable material is wasted or lost due to the fact that there is no thorough coordination between the different stations. I urged that this be considered more than 10 years ago in the hope that materials produced at one station might be tested at other stations.

OKLAHOMA—*C. B. Cross.*

More rigorous tests of material under controlled conditions to determine the influence of as many factors in the environment as possible and to shorten the period of search for particular characters through exaggeration of the limiting factor for elimination of mediocre to poor material. Either technical training for the plant breeder in plant pathology, technical training for the plant pathologist in genetics, or the stationing of both in connection with research institutions.

Oregon—*G. R. Hyslop.*

More funds.

Texas—*P. C. Mangelsdorf.*

Better planning of experiments to make proper use of statistical methods.

Utah—*D. C. Tingey.*

We would welcome some arrangement whereby we could get our promising strains tested in other areas for resistance to different physiologic forms of loose and covered smut, also winter-hardiness, and for milling value, both for bread-making and other purposes.

The suggestions of the writer are briefly as follows. We should have—

1. A greater technical knowledge of the nature and value of individual characters.
2. More fundamental genetic research on the inheritance of individual characters.
3. Practical breeding conducted with a genetic background and plan for combining the most valued characters into one variety.
4. Greenhouse and field facilities for growing two or even three generations of early hybrid material a year.
5. Artificial conditions in laboratory or field for disease, drought, heat, cold, and insect infection and control.
6. A regional basis, and well-located stations, for testing new hybrid selections for yield, disease resistance, winter-hardiness, etc.
7. Equipment and assistance for testing early generation strains and new varieties for quality.
8. Land and facilities for increasing pure seed, and a uniform plan for distributing the foundation stock seed of new varieties having superior germ plasm.

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Appendix

Commercial Varieties of Wheat Grown in the United States, by Classes and in the Order of Estimated Acreage in 1929

Hard red spring: Marquis, Ceres, Supreme, Preston, Kota, Ruby, Haynes Bluestem, Montana King, Progress, Red Fife, Power, Java, Red Bobs, Humpback, Marquillo, Kinney, Ladoga, Garnet, Sea Island, Huston, Reward, Renfrew, Kitchener, Whiteman, Hope, Marvel, Converse, Prelude, Ghirka, Champlain, Stanley, Reliance, Dixon.

Durum: Pentad, Kubanka, Mindum, Monad, Acme, Nodak, Kahla, Arnautka, Peliss, Barnatka.

Hard red winter: Turkey, Blackhull, Kanred, Nebraska No. 60, Ridit, Michikof, Iobred, Superhard, Minturki, Karmont, Montana No. 36, Ilred, Alton, Mosida, Newturk, Nebraska No. 6, Redhull, Eagle Chief, Ioturk, Wisconsin Pedigree No. 2, Bacska, Iowa No. 404, Ashkof, Sherman, Iowin, Oro, Regal, Early Blackhull.

Soft red winter: Fultz, Fulcaster, Trumbull, Red May, Leap, Poole, Mediterranean, Currell, Nittany, Harvest Queen, Red Rock, Red Wave, Fulhio, Purkof, Rudy, Triplet, Jones Fife, Forward, Purplestraw, Nigger, V. P. I. 131, Flint, Russian Red, Red Russian, Mammoth Red, Gladden, Fultzo-Mediterranean, Diehl-Mediterranean, V. P. I. 112, Hybrid 123, Gipsy, Goens, Berkeley Rock, Russian, Denton, China, Portage, Red Clawson, Climax, Ashland, Mealy, Rupert, Silversheaf, Rice, Lofthouse, Odessa, Prosperity, Penquite, Shepherd, Coppei, Illini Chief, Redhart, Walker, Sol, Grandprize, Minhardi, Wheedling, Valley, Ruddy, Oakley, Mayview, Nabob, Imperial Amber, Gold Drop, Golden Cross.

White: Goldcoin, Baart, Federation, Pacific Bluestem, Hybrid 128, Dicklow, Quality, Bunyip, Jenkin, Sonora, Albit, Hard Federation, Dawson, Defiance, White Federation, Rink, White Winter, Surprise, Wilhelmina, Propo, Little Club, Honor, Onas, Pilcraw, Galgalos, Hybrid 143, Eaton, Greeson, Redchaff, Prohibition, Silvercoin, Touse, Big Club, Oregon Zimmerman, Sevier, Kofod, Escondido, Powerclub, Democrat, Palisade, Martin, Foisy, Allen, Longberry No. 1, Windsor, Bluechaff, New Zealand, Pusa No. 4, Genesee Giant, Utac, White Odessa, Hard Baart, Axminster.

Recommended Varieties of Wheat for Commercial Growing, by States and Classes

[NOTE.—Some varieties are known by several names. The names here used for the standard and improved varieties that have been registered are in caps, and for synonyms and new varieties not yet registered, in lower case]

ALABAMA:
Soft red winter: Alabama Bluestem (PURPLESTRAW).

ARIZONA:
White: BAART.

ARKANSAS:
Soft red winter: Alabama Bluestem (PURPLESTRAW), Early Ripe (RED MAY), FULTZ, MEDITERRANEAN, FULCASTER.

CALIFORNIA:
White: (Common) BAART, PACIFIC BLUESTEM, WHITE FEDERATION, ONAS, BUNYIP, FEDERATION, Escondido, SONORA; (club), Poso, BIG CLUB.

COLORADO:
Hard red winter: KANRED, TURKEY.
Hard red spring: KOMAR.
White: (Irrigated) DICKLOW.

DELAWARE:
Soft red winter: GLADDEN, FORWARD, NITTANY.

GEORGIA:
Soft red winter: GASTA, PURPLESTRAW, FULCASTER.

Idaho:

Hard red winter: MOSIDA, TURKEY, KANRED.

White: (Common winter) Fortyfold (GOLDCOIN); (common spring) FEDERATION, DICKLOW, PACIFIC BLUESTEM, BAART; (club winter) ALBIT, HYBRID 128; (club spring) JENKIN.

Illinois:

Hard red winter: (Northern Illinois) ILRED, IOTURK, MINTURKI, PURKOF, WISCONSIN PEDIGREE NO. 2; (central Illinois) CHEYENNE, TENMARQ, Illinois No. 2.

Soft red winter: (Southern Illinois) FULCASTER, FULHIO, Red Sea (MEDITERRANEAN), Michigan Amber (RED MAY).

Indiana:

Soft red winter: Michigan Amber (RED MAY), FULTZ, TRUMBULL, RUDY, POOLE.

Iowa:

Hard red winter: IOWIN, IOBRED (for combine harvesting), TURKEY.

Kansas:

Hard red winter: TURKEY, KANRED, TENMARQ, BLACKHULL.

Soft red winter: KAWVALE, HARVEST QUEEN, FULCASTER, Clarkan.

Kentucky:

Soft red winter: ASHLAND, Kentucky 47 (CURRELL), FULCASTER, TRUMBULL, KAWVALE.

Maine:

Hard red spring: GARNET, MARQUIS, RED FIFE.

Maryland:

Soft red winter: MAMMOTH RED, Leapland, LEAP, CURRELL.

Michigan:

White: (Winter) American Banner (DAWSON).

Soft red winter: RED ROCK, BALDROCK.

Minnesota:

Hard red spring: MARQUIS, CERES, THATCHER.

Durum: MINDUM.

Hard red winter: MINTURKI.

Missouri:

Soft red winter: Michigan Wonder (RED MAY) and Early May, FULCASTER, POOLE, FULHIO, HARVEST QUEEN.

Montana:

Hard red winter: MONTANA NO. 36, KARMONT, NEWTURK, YOGO.

Hard red spring: MARQUIS, SUPREME.

White: (Irrigation) FEDERATION.

Nebraska:

Hard red winter: CHEYENNE, NEBRASKA NO. 60, TURKEY.

Hard red spring: CERES, KOMAR.

Nevada:

White: FEDERATION, BAART.

New Jersey:

Soft red winter: LEAP, POOLE.

White: (Winter) DAWSON.

New Mexico:

Hard red winter: TURKEY, KANRED.

New York:

White: HONOR, Junior No. 6 (GOLDCOIN).

Soft red winter: FORWARD, Valprize.

North Carolina:

Soft red winter: LEAP, FULCASTER, PURPLESTRAW, Redhart.

North Dakota:

Hard red spring: CERES, MARQUIS.

Durum: KUBANKA, MINDUM.

Ohio:

Soft red winter: TRUMBULL, FULHIO, GLADDEN, NABOB.

Oklahoma:

Hard red winter: TURKEY, BLACKHULL, KANRED, (and with qualifications) NEBRASKA NO. 60, CHEYENNE, TENMARQ, Eagle Chief.

Soft red winter: FULCASTER, HARVEST QUEEN, DENTON, (and with qualifications) KAWVALE.

OREGON:

White: (Common spring) FEDERATION, BAART, WHITE FEDERATION, RINK, Oregon Zimmerman; (common winter) WHITE WINTER. Holland (Wilhelmina); (club winter) HYBRID 128, Hood.

Hard red winter: TURKEY, RIO, ORO.

Hard red spring: HUSTON.

PENNSYLVANIA:

Soft red winter: NITTANY, FORWARD, LEAP.

SOUTH CAROLINA:

Soft red winter: PURPLESTRAW, Redhart.

SOUTH DAKOTA:

Hard red spring: CERES, MARQUIS, REWARD.

Durum: MINDUM, KUBANKA.

Hard red winter: MINTURKI, TURKEY.

TENNESSEE:

Soft red winter: FULCASTER, FULTZ, MEDITERRANEAN, RED MAY.

TEXAS:

Soft red winter: DENTON, MEDITERRANEAN.

Hard red winter: TENMARQ, TURKEY. KANRED, BLACKHULL.

UTAH:

White: DICKLOW, FEDERATION.

Hard red winter: RELIEF, TURKEY, Utah Kanred.

VIRGINIA:

Soft red winter: V. P. I. 131, V. P. I. 112, FULCASTER, PURPLESTRAW, FORWARD, FULTZ, LEAP.

WASHINGTON:

White: (Club winter) HYBRID 128, ALBIT; (common spring) BAART, FEDERATION, PACIFIC BLUESTEM; (club spring JENKIN.

Hard red winter: TURKEY, RIDIT, ORO.

Soft red winter: TRIPLET, JONES FIFE.

WEST VIRGINIA:

Soft red winter: FULCASTER, FULHIO.

WISCONSIN:

Hard red winter: TURKEY, WISCONSIN PEDIGREE NO. 2, ASHKOF.

Hard red spring: PROGRESS, STURGEON.

WYOMING:

Hard red spring: MARQUIS, CERES.

Durum: KUBANKA.

White: BAART, HARD FEDERATION.

Hard red winter: TURKEY.

TABLE 2.—*Recommended commercial varieties of unknown origin or introduced and developed by selection or hybridization and first distributed in the United States by farmers, seedsmen, or private breeders*

Method of origin and variety	Year distributed	By whom	City or State	From—	Commercial acreage 1929	Commercial acreage 1934
UNDETERMINED						
Purplestraw	1822'		Virginia		150,014	306,028
Poole	1884		Ohio		600,817	672,564
Jenkin	1895		Washington		92,199	47,930
Rink	1909		Oregon		30,053	7,685
INTRODUCTION						
Mediterranean	1819	John Gordon	Wilmington, Del	Italy	542,793	519,261
Sonora	1825	Pima and Yuma Indians.	California	Mexico	91,852	50,681
Pacific Bluestem.	1852		do	Australia	363,955	167,582
White Winter	1855		Oregon	England	26,710	16,377
Red Fife	1860	J. W. Clark	Wisconsin	Poland	28,101	19,509
Big Club	1866		California	Chile	4,236	36,830
Turkey	1873	Russian Mennonites.	Newton and Halstead, Kans.	Russia	15,542,434	14,828,939
Huston	1876	Mr. Belshaw	Eugene, Oreg	Bulgaria	6,620	12,643
Dawson	1893		New York	Canada	42,578	356,108
Marquis	1913	Commercial seed and grain firms.	North Dakota, Minnesota.	Canada	11,786,590	8,510,141
Bunyip	1918	Sperry Flour Mills Co.	Stockton, Calif	Australia	116,435	71,058
Garnet	1927	Seedsmen	North Dakota, Minnesota.	Canada	8,958	11,038
Reward	1928	do	North Dakota, South Dakota.	do	6,520	230,952
SELECTION						
Red May	1830	General Harmon.	Virginia	Virginia May.	799,161	977,421
Fultz	1862	Abraham Fultz	Pennsylvania	Lancaster.	1,446,830	1,870,380
Rudy	1871	M. Rudy	Troy, Ohio		191,078	211,991
Currell	1884	W. E. Currell.	Virginia	Fultz	430,596	480,478
Goldcoin.	1890	Ira M. Green	Aron, N. Y	Diehl Mediterranean.	892,371	437,734
Harvest Queen	1897	E. S. Marshall	De Soto, Kans		359,857	379,897
Leap	1905	Mr. Leap	Virginia	Mediterranean	673,613	708,903
Dicklow	1910	James Holly	(Utah County), Utah	California Club.	253,421	176,022
Blackhull	1917	Earl G. Clark	Sedgwick, Kans	Turkey	5,959,067	6,617,379
Redhart	1923	Coker's Pedigreed Seed Co.	Hartsville, S. C	Flint	2,310	112,392
Oregon Zimmerman.	1921	Ed. Zimmerman	Shedd, Oreg	Surprise	3,474	14,278
Eagle Chief	1927	C. H. Hyde.	Alva, Okla.	Kharkof	6,881	20,214
Clarkan	1929	Earl G. Clark	Sedgwick, Kans	Natural hybrid.		
HYBRIDIZATION						
Fulcaster	1886	S. M. Schindel.	Hagerstown, Md.	Fultz × Lancaster.	1,400,057	1,395,122
Jones Fife	1889	A. N. Jones	Newark, N. Y	Fultz-Mediterranean × Russian Velvet	167,416	117,736
Total					42,027,003	39,385,273

TABLE 3. —*Commercial varieties introduced or developed and first distributed in the States by State and Federal agricultural experiment stations*

[An asterisk (*) indicates U. S. Department of Agriculture cooperation]

State, station, and variety	Year distributed	By whom	Superior characters	Methods used	Parent varieties or source	Commercial acreage in United States 1929	Commercial acreage in United States 1934
Alabama:							
Experiment Station, Auburn							
Alabama Bluestem	1914	J. F. Duggar	Cold resistant, high yield	Selection	Purplestraw		
Arizona:							
Experiment Station, Tucson:							
BAART*	1910	G. W. Freeman	Drought resistance	Introduction	Australia	766,547	794,774
Hard Baart	1922	W. E. Bryan	Hard texture	Selection	Baart		
Arkansas:							
Experiment Station, Fayetteville:							
Arkansas No. 105	1918	L. W. Osborn	High yield	do	Red May		
California:							
Experiment Station, Davis:							
WHITE FEDERATION.*	1919	V. H. Florell	do	Introduction	Australia	38,401	105,267
ONAS*	1920	G. W. Hendry	do	do	do	17,330	28,398
Escondido	1922	W. W. Mackie	Rust tolerant	Selection	Defiance	2,125	15,439
Poso	1924	do	Earliness, yield, nonshattering	Hybridization	Little Club × Clarendon		1,732
Colorado:							
Experiment Station, Fort Collins:							
REGENERATED DEFIANCE.	1903	A. H. Danielson	Yield	Selection	Defiance		
Marquis No. 1	1930	D. W. Robertson	High yield	do	Marquis		
Georgia:							
Experiment Station, Athens:							
Cherokee*	1929	R. R. Childs	High yield, earliness, stiff straw	do	C. I. No. 4159 (from Peru)		2,763
GASTA	1931	R. P. Bledsoe	High yield, earliness, uniformity	do	Purplestraw		952
Idaho:							
Experiment Station, Moscow:							
MOSIDA	1926	H. W. Hulbert	High yield, winter hardy, stiff straw	Hybridization	Fultzo-Mediterranean × Turkey	12,392	16,118

TABLE 3.—*Commercial varieties introduced or developed and first distributed in the States by State and Federal agricultural experiment stations*—Continued

[An asterisk (*) indicates U. S. Department of Agriculture cooperation]

State, station, and variety	Year distributed	By whom	Superior characters	Methods used	Parent varieties or source	Commercial acreage in United States 1929	Commercial acreage in United States 1934
Illinois:							
Experiment Station, Urbana:							
ILRED	1921	L. H. Smith	High yield	Selection	Turkey	24, 190	7, 530
Illinois No. 2	1931	do	Winter hardy	do	Indiana Swamp		968
Indiana:							
Purdue Experiment Station, LaFayette.							
MICHIKOF	1921	A. T. Wiancko	Winter hardy, hard grain	Hybridization	Michigan Amber × Malakof	139, 107	91, 923
PURKOF	1923	do	High yield, winter hardy	do	do	199, 816	300, 357
Purdue No. 1	1934	G. H. Cutler	High yield, quality for pastry flour.	do	Michigan Amber × Rudy		275
Iowa:							
Experiment Station, Ames:							
IOWA 404	1907	L. C. Burnett	Yield, winter hardiness	Selection	Minnesota No. 529	1, 996	
IOBRED*	1915	do	Stiff straw, quality	do	Ia. No. 1661	107, 892	112, 874
IOTURK*	1908	do	High yield	do	Turkey	4, 149	9, 246
IOWIN*	1918	do	Rust resistance, stiff straw, high yield.	do	Theiss	1, 008	8, 629
Kansas:							
Experiment Station, Manhattan:							
Kharkof*	1900	M. A. Carleton	Winter hardiness and high yield	Introduction	Russia	383, 243	285, 456
KANRED*	1917	H. F. Roberts, W. M. Jardine, L. E. Call, S. C. Salmon.	Earliness, winter hardy, high yield	Selection	Crimean C. I. 1435	3, 490, 184	2, 928, 980
KAWVALE*	1931	J. H. Parker, C. O. Johnston, S. C. Salmon, H. H. Laude.	Earliness, winter hardy, resistance to leaf rust and Hessian fly, high yield.	do	Indiana Swamp		41, 487
TENMARQ*	1932	J. H. Parker, S. C. Salmon, H. H. Laude.	Earliness, stiff straw, high yield, excellent quality.	Hybridization	P 1066 x Marquis		177, 746
Kentucky:							
Experiment Station, Lexington:							
ASHLAND	1915	E. J. Kinney	Stiff straw, high yield	Selection	Fultz	8, 753	3, 758
Kentucky 47	1918	do	Earliness, stiff straw	do	Currell		

Maryland:							
Experiment Station, College Park:							
MAMMOTH RED	1914	W. B. Hanger	*Septoria nodorum* resistant	do	Fulcaster	54,385	43,713
Leapland	1924	W. B. Kemp	High yield, stiff straw	do	Leap		
Michigan:							
Experiment Station, East Lansing:							
RED ROCK	1913	F. A. Spragg	Yield, stiff straw, good bread flour	do	Plymouth Rock	261,246	219,706
Berkeley Rock	1922	do	Hard texture, winter hardy, bunt and loose smut resistance.	Hybridization	Berkeley × Red Rock	17,433	21,780
BALDROCK	1930	F. A. Spragg, E. E. Down, H. M. Brown	Stiff straw, winter hardy, beardless, desirable soft flour.	Selection (from natural cross)	Red Rock		25,434
Minnesota:							
Experiment Station, St. Paul:							
Spring wheat:							
HAYNES BLUESTEM (Minn 169).	1899	W. M. Hays, Andrew Boss.	Yield and quality	Selection	Bluestem	72,943	22,322
GLYNDON (Minn 163).	1899	do	do	do	Red Fife		
MARQUILLO*	1929	H. K. Hayes, O. S. Aamodt.	Stem rust resistance, stiff straw	Hybridization	Marquis × Iumillo	10,150	135,185
THATCHER*	1934	H. K. Hayes, E. R. Ausemus, E. C. Stakman, R. S. Dunham.	Stem rust resistance, stiff straw, quality, yield	do	Marquis-Iumillo × Marquis-Kanred.		1,823
Durum:							
MINDUM*	1917	C. P. Bull, H. K. Hayes, J. H. Parker.	Macaroni quality and yield	Selection	From mixtures in spring wheat variety.	322,151	446,399
Winter wheat:							
MINHARDI	1917	H. K. Hayes, R. J. Garber.	Winter hardy, yield, fair quality	Hybridization	Turkey × Odessa	886	2,105
MINTURKI	1917	H. K. Hayes, R. E. Hodgson.	Yield, resistance to stem rust and bunt.	do	do	89,028	165,639
Missouri:							
Experiment Station, Columbia:							
Fulcaster, Selection No. 8y.	1912	L. J. Stadler	Yield	Selection	Fulcaster		
Early May W2083	1925	do	Early maturity, yield	do	Early May		
Mich. Wonder, Selection No. 21.	1934	do	Yield	do	Michigan Wonder		
Montana:							
Experiment Station, Bozeman:							
MONTANA NO. 36	1912	A. Atkinson	Yield, high quality, winter hardy	do	Kharkof	31,028	18,674
SUPREME	1924	J. J. Jenson	Yield, earliness	Introduction	Canada	299,840	188,401
Judith Basin Branch Station, Moccasin:							
KARMONT*	1922	E. L. Adams, N. C. Donaldson	Yield × quality	Selection	Kharkof	85,935	90,448

TABLE 3.—*Commercial varieties introduced or developed and first distributed in the States by State and Federal agricultural experiment stations*—Continued

[An asterisk (*) indicates U. S. Department of Agriculture cooperation]

State, station, and variety	Year distributed	By whom	Superior characters	Methods used	Parent varieties or source	Commercial acreage in United States 1929	Commercial acreage in United States 1934
Montana—Continued.							
Judith Basin Branch Station, Moccasin—Con.							
NEWTURK*	1927	J. A. Clark, R. W. May	Awnless, high yield, quality	Hybridization	Newton × Turkey	12,390	21,790
YOGO*	1933	K. S. Quisenberry, B. B. Bayles, J. L. Sutherland.	Winter hardy, bunt resistance, high yield.	do	Minturki × Beloglina × Buffum		
Nebraska:							
Experiment Station, Lincoln:							
NEBRASKA NO. 60	1918	T. A. Kiesselbach	Hardiness, yield, baking quality	Selection	Turkey	345,163	649,839
CHEYENNE	1930	T. A. Kiesselbach, A. Anderson.	Superior yield, lodge and shatter resistance, and Hessian fly tolerance.	do	Crimean C. I. 1435		42,575
New York:							
Experiment Station, Ithaca:							
HONOR*	1907	H. J. Webber	Yield, hardiness	do	Dawson	17,368	68,897
FORWARD*	1912	H. H. Love	Yield, hardiness, smut resistance	do	Fulcaster	155,172	258,329
Valprize*	1913	do	Smut resistance, stiff straw	Hybridization	Valley × Grandprize		4,816
North Carolina:							
Experiment Station, Raleigh:							
Leaps No. 12	1920	R. Y. Winters, G. M. Garren	Yield, stiff straw, quality	Selection	Leap		
Leaps No. 32	1920	do	do	do	do		
North Dakota:							
Experiment Station, Fargo:							
POWER (Station 66)	1892	W. M. Hays, J. H. Shepperd	High yield	do	Red Fife	20,160	17,432
PENTAD*	1911	H. L. Bolley	Stem resistance to rust	Introduction	Russia	1,004,228	309,822
MONAD*	1913	do	do	do	do	94,682	17,977
KOTA*	1920	L. R. Waldron, J. A. Clark.	Resistance to stem rust	Selection	Monad	250,985	59,890
CERES*	1926	L. R. Waldron	Stem rust, drought resistance, yield.	Hybridization	Marquis × Kota	347,632	4,453,487
KOMAR*	1931	do	Quality, more rust resistant than Ceres	do	do		12,412
Dickinson Substation, Dickinson:							
NODAK*	1923	R. W. Smith	Rust resistance	Selection	Kubanka	36,910	17,635

Northern Great Plains Field Station, Mandan:							
RELIANCE*	1926	J. A. Clark	High yield	Hybridization	Kanred × Marquis	311	1,722
Ohio:							
Experiment Station, Columbus:							
TRUMBULL	1916	C. G. Williams	Loose smut resistance, yield	Selection	Fultz	902,699	1,135,641
GLADDEN	1916	do	Winter hardy	do	Gipsy	41,735	34,896
PORTAGE	1916	do	Hardy, yield	do	Poole	13,067	23,387
FULHIO	1918	do	High yield	do	Fultz	254,086	533,838
NABOB	1928	L. E. Thatcher	do	do	Nigger	257	1,771
Oklahoma:							
Experiment Station, Stillwater:							
Sibley No. 81	1916	A. Daane	Yield	do	Sibley New Golden		22,737
Sibley No. 62	1916–17	do	Yield, leaf rust resistance	do	do		
Oregon:							
Experiment Station, Corvallis:							
Wilhemina	1910	G. R. Hyslop	Yield, winter hardiness	Introduction	Netherlands	23,004	37,545
Hood	1932	D. D. Hill	Winter hardiness	Selection	Jenkin		1,970
Sherman County Branch Station, Moro:							
FEDERATION*	1920	D. E. Stephens	Yield, hardiness, stiff straw	Introduction	Australia	732,867	697,421
HARD FEDERATION*	1920	do	Drought resistance, earliness	do	do	61,781	9,110
SHERMAN*	1926	M. A. Carleton, J. A. Clark, D. E. Stephens	Smut resistance, yield, stiff straw	Hybridization	Budapest-Turkey × Zimmerman-Turkey.	1,266	5,159
ORO*	1927	H. M. Woolman, D. E. Stephens.	Bunt resistance, yield, stiff straw	Selection	Turkey	774	3,077
RIO*	1930	D. E. Stephens, H. M. Woolman.	Smut resistance, yield	do	do		871
REX*	1933	D. E. Stephens, J. F. Martin.	Yield, bunt resistance, strong straw.	Hybridization	White Odessa × Hard Federation		
Pennsylvania:							
Experiment Station, State College:							
NITTANY (Pa 44)	1909	C. F. Noll	Good yield	Selection	Fulcaster	398,312	409,222
South Dakota:							
Experiment Station, Brookings:							
KUBANKA*	1901	M. A. Carleton, J. S. Cole	Yield, rust resistance	Introduction	Russia	724,864	687,379
ACME*	1914	M. Champlin	do	Selection	Kubanka	72,938	106,783
U. S. Field Station, Redfield:							
HOPE*	1926	E. S. McFadden	Near immune from stem rust	Hybridization	Marquis × Yaroslav (emmer)	3,405	16,250
Texas:							
Substation no. 6, Denton:							
DENTON	1918	A. H. Leidigh, C. H. McDowell, P. B. Dunkle.	High yield, stiff straw, rust resistance.	Selection	Mediterranean	16,270	48,596
Mediterranean No 81	1918	do	do	do	do		

Table 3.—*Commercial varieties introduced or developed and first distributed in the States by State and Federal agricultural experiment stations*—Continued

[An asterisk (*) indicates U. S. Department of Agriculture cooperation]

State, station, and variety	Year distributed	By whom	Superior characters	Methods used	Parent varieties or source	Commercial acreage in United States: 1929	Commercial acreage in United States: 1934
Utah:							
Experiment Station, Logan:							
Utac (spring)	1926	George Stewart	Strong straw, yield	Hybridization	Dicklow × Sevier	418	610
RELIEF* (winter)	1931	D. C. Tingey	Resistance to most forms of bunt in Utah, yield.	do	Hussar × Turkey		77
Virginia:							
Experiment Station, Blacksburg:							
V. P. I. 131	1905	L. Carrier	High yield, heavy straw	Selection	Fulcaster	80,135	106,292
V. P. I. 112	1905	do	Stiff straw, high yield	do	Poole	32,490	12,550
Washington:							
Experiment Station, Pullman:							
HYBRID 128	1907	W. J. Spillman, E. E Elliott, C. W. Lawrence	Yield, stiff straw, winter hardy	Hybridization	Jones Fife × Little Club	356,910	142,605
HYBRID 123	1907	do	Facultative, prolific	do	do	26,053	3,037
HYBRID 63	1907	do	Quality, drought resistance	do	Turkey × Little Club		5,449
HYBRID 143	1908	do	High test weight	do	White Tract × Little Club	10,198	6,159
TRIPLET	1918	E. F. Gaines	Winter hardy, prolific	do	Jones Fife-Little Club × Jones Fife-Turkey.	168,018	123,150
RIDIT*	1924	do	Smut resistance, quality	do	Turkey × Florence	166,411	159,402
ALBIT*	1927	do	Smut resistance	do	Hybrid 128 × White Odessa	78,190	392,483
Wisconsin:							
Experiment Station, Madison:							
WISCONSIN PEDIGREE NO. 2.	1906	R. A. Moore, A. L. Stone	Yield, hardiness, milling and baking quality.	Selection	Turkey	3,948	1,995
BACSKA	1908	E. J. Delwiche	Milling and baking quality	do	Bacska	2,281	16
ASHKOF	1911	do	Winter hardiness, yield, quality	do	Malakof	1,382	2,058
PROGRESS (spring)	1916	do	Earliness, stem rust resistance, stiff straw, high protein.	do	Early Java	33,193	92,546
Peninsular Branch Station, Sturgeon:							
STURGEON	1934	do	Stem rust resistance, yield, quality	Hybridization	Progress × Marquis		28
Total						12,954,141	17,077,034

United States Breeding Stations, Wheat Breeders, Breeding Methods, Commercial Varieties, Promising New Strains, Present Work, and Objectives

[An asterisk (*) denotes U. S. Department of Agriculture employee. Varieties in italics are recommended but were not developed by station]

UNITED STATES

(1) DEPARTMENT OF AGRICULTURE, Washington, D. C.:

WHEAT BREEDERS:

Early workers—M. A. Carleton*, C. R. Ball*, C. E. Leighty*, J. H. Martin.*

Present workers—

S. C. Salmon*, in charge, Wheat Investigations.

J. A. Clark*, hard red spring and durum wheat breeding; coordinator of cooperative improvement work in Minnesota, North Dakota, South Dakota, Montana, and Wyoming.

K. S. Quisenberry*, hard red winter wheat breeding; coordinator of improvement work in Nebraska, Kansas, Colorado, Oklahoma, and Texas.

B. B. Bayles*, white wheat breeding; coordinator of cooperative improvement work in Washington, Oregon, Idaho, Utah, California, and Arizona.

J. W. Taylor*, soft red winter wheat breeding.

Wm. J. Sando*, species hybrids, and cytology.

(2) ARIZONA, Experiment Station, Tucson:

WHEAT BREEDERS:

Early worker—G. F. Freeman.

Present workers—W. E. Bryan, E. H. Pressley, A. T. Bartel.*

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1905–20):	
Baart (1910).	Bobin.
Selection (1912–25):	
Hard Baart (1922).	Australian Club selection.

Hybridization (1912–35).

Present work—Crosses of Ridit × Pusa, Escondido × Hussar, and Ridit × Sonora for bunt resistance, high yield, and hard texture of kernels; also crosses of the above with Federation derivatives in order to increase strength of straw.

(3) ARKANSAS, Experiment Station, Fayetteville:

WHEAT BREEDERS:

Early worker—L. W. Osborn.

Present worker—C. K. McClelland.

BREEDING METHODS:

Commercial varieties—

Introduction (1920–25).

Selection (1918–35):
Arkansas No. 105 (1918).

Present work—Twenty-five strains out of an original lot of some 400 head selections from Alabama Bluestem, Early Ripe, Fultz, Mediterranean, and Red Wonder, for high yield and purification of seed.

(4) CALIFORNIA, University Farm, Davis:

WHEAT BREEDERS:

Early workers—G. W. Shaw, A. J. Gaumnitz, G. W. Hendry, B. A. Madson, W. W. Mackie, V. H. Florell.*

Present workers—F. N. Briggs, G. A. Wiebe.*

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1907–35):	
Pacific Bluestem, *Sonora*, *Big Club*. Baart and Bunyip (1915), White Federation and Federation (1919), and Onas (1920).	Pusa No. 4 (India).
Selection (1915–35): Escondido (1922).	
Hybridization (1908–35):	
Poso (1924).	Ramona (Hard Federation × Bunyip). Bronco (Hard Federation × Prelude).

Present work—Martin (resistant to bunt) crossed and backcrossed with Baart, Pacific Bluestem, White Federation, Onas, Big Club, Sonora, Federation, Hard Federation, Ramona, Pusa No. 4, Bunyip, Escondido, and Poso, to develop bunt resistant strains similar to the standard varieties. Hope (resistant to rust) crossed and backcrossed with Baart, White Federation, and Big Club to develop rust resistant strains similar to these standard varieties.

(5) Department of Agriculture, Sacramento (at Bird's Landing):

WHEAT BREEDERS:

W. B. Cartwright,* G. A. Wiebe.*

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1925–30).	Dawson.
Selection (1928–32).	Velvet Node (C. I. 5877).
Hybridization (1930–35).	

Present work—Dawson and Velvet Node (resistant to Hessian fly) crossed with Big Club and Poso to develop adapted white spring wheats for the Montezuma Hills section which are resistant to Hessian fly attack.

(6) COLORADO, Experiment Station, Fort Collins:

WHEAT BREEDERS:

Early workers—A. E. Blount, A. H. Danielson, W. W. Austin, G. W. Deming.

Present worker—D. W. Robertson.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1907–25): *Turkey*, *Dicklow*, *Marquis* (1918). *Kanred* (1920), *Ceres* (1926) and *Komar* (1930).	
Selection (1886–1930): Regenerated Defiance (1903), Marquis No. 1 (1930).	Turkey Selection Colo. 351.
Hybridization (1921–35).	

Present work—Kanred × Marquis, Turkey × Marquis, and Minhardi × Marquis for winter hardiness and milling and baking quality. Multiple hybrids,

(Hard Federation-Marquis × Marquis) × Kanred and Kanred × (Hard Federation-Marquis) × Prelude for earliness, stiff straw, and rust evasion. Kanred × Hope and Kanred × Hope-Hard Federation for rust resistance, earliness, and stiff straw. Both spring and winter selections are made from these winter × spring wheat crosses. Ridit × Kanred-Hope and other crosses for smut resistance.

(7) United States Dry Land Field Station, Akron:

WHEAT BREEDERS:

Early workers—Clyde McKee*, C. H. Clark*, G. A. McMurdo*, F. A. Coffman*.

Present workers—J. J. Curtis* (D. W. Robertson).

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1910-20).	Selection:
Kanred (1918).	Akrona (Arnautka).
Selection (1910–35).	Kanred 0166 (Kanred).
Hybridization (1930-35).	"Mutant" Akron No. 7, C. I. 11660.

(8) DELAWARE, Experiment Station, Newark:

WHEAT BREEDERS:

Early worker—A. E. Grantham.

Present workers—G. L. Schuster, C. E. Phillips.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1907–20):	Delaware Selection No. 2924.
Gladden, Forward, Nittany.	Delaware Selection No. 2929.
Selection (1930-35).	Delaware Selection No 3618.

Present work—A total of 5,727 head selections were made from 800 Delaware farms in 1930 for testing purity, stooling habits, disease resistance, stiffness of straw, and yield In 1934, 3,731 of these selections were under trial in rod rows.

(9) GEORGIA, Experiment Station, Athens:

WHEAT BREEDERS: R. P. Bledsoe, S. J. Hadden, R. R. Childs.*

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1921–35):	Selection:
Purplestraw, Fulcaster	Wabash (Fultz).
Selection (1921–35):	Hybridization:
Cherokee (1929).	H-49-5-10 3-3-1-1
Gasta (1931).	H1-142-1-1-1
Hybridization (1921–35).	

Present work—Purplestraw-Kanred × Purplestraw (Cross H49), P1068-1 × Purplestraw (Cross H1), double-cross C. I. 3756-Mediterranean × Dietz-C. I. 3756, and other crosses, backcrosses, and double crosses for winter hardiness, strong straw, resistance to leaf and stem rust, and high yield. Selections are made for the soft red winter type desirable for southern production. The above selection and others from the H49 cross have resistance to both stem and leaf rust.

(10) IDAHO, Experiment Station, Moscow:

WHEAT BREEDERS:

Early workers—H. W. Hulbert, V. H. Florell*, F. L. Burkart.

Present worker—C. A. Michels.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1915–35): *Albit, Hybrid 128, Turkey, Kanred, Goldcoin* (winter), and *Dicklow, Federation, Pacific Bluestem, Jenkin* and *Baart* (spring).	
Selection (1925–35).	Jenkin selection.
Hybridization (1930–35): Mosida (1926).	

Present work—Mosida × Albit, Mosida × White Odessa, Mosida × Fortyfold, Mosida × Ridit, winter wheat crosses for winter hardiness, high yield, strong straw, and resistance to drought, foot rot, and bunt.

(11) Aberdeen Substation, Aberdeen:

WHEAT BREEDERS:

Early workers—L. C. Aicher*, G. A. Wiebe*, L. L. Davis*.

Present worker—Harland Stevens*.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1913–35): Dicklow (1915), Federation (1924)	Hybridization: Federation × Dicklow, C. I. 11415.
Selection (1915–35).	Bobs × Federation, C. I. 11416.
Hybridization (1923–35).	

Present work—Federation × Dicklow, Hard Federation × Dicklow, Bobs × Dicklow, Bobs × Federation, and other crosses of spring wheat for growing under irrigation having high yield, stiff straw, and the soft kernels of Dicklow desirable for pastry flour.

(12) ILLINOIS, Experiment Station, Urbana:

WHEAT BREEDERS:

Early workers—L. H. Smith, C. E. Rosenquist, B. Koehler.

Present worker—O. T. Bonnett.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction: *Ioturk, Minturki, Purkof, Wisconsin Ped. No. 2, Cheyenne, Tenmarq, Fulcaster, Fulhio, Mediterranean, Red May.*	Selection: Illinois No. 131, Illinois No. 84.
Selection (1905–35): Ilred (1921), Illinois No. 2 (1931).	
Hybridization (1905–35).	

Crosses involving Minhardi, Purkof, Gladden, Minturki, Illinois No. 2, Kanred, Illini Chief, Fulhio, Fulcaster, and Harvest Queen to produce winter hardy, soft red winter wheat varieties of good quality for both bread and pastry flour.

(13) INDIANA, Experiment Station, LaFayette:

WHEAT BREEDERS:

Early workers—E. B. Mains, A. T. Wiancko, R. R. Mulvey.

Present workers—G. H. Cutler, W. W. Worzella, L. E. Compton, Ralph M. Caldwell*.

Breeding Methods:

COMMERCIAL VARIETIES

Introduction (1918–35):
Red May, Fultz, Trumbull, Rudy, Poole.

Selection (1918–35).

Hybridization (1906–35):
Michikof (1921), Purkof (1923), Purdue No. 1 (1934).

PROMISING NEW STRAINS

Selection:
Fultz selection C. I. 11384-3.

Hybridization·
Purdue No. 4.
Hope × Hussar G. 2343A-4-55.

Present work—In the earlier work, Michigan Amber, Rudy, and Fultz were crossed with Malakof to combine good quality in both hard and soft winter wheat strains of greater winter hardiness. In recent work, Hope × Hussar, Kanred × Red Rock, Kanred × Gipsy, and Fultz selection × Hungarian crosses for resistance to loose smut, bunt, stem rust, leaf rust, mildew, head scab, and other diseases. The Hope × Hussar strain listed above is resistant to five major wheat diseases.

(14) IOWA, Experiment Station, Ames:

Wheat Breeders: L. C. Burnett, J. B. Wentz.

Breeding Methods:

COMMERCIAL VARIETIES

Introduction (1900–1935):
Turkey.

Selection (1906–35):
Iowa No. 404 (1907), Ioturk (1908). Iobred (1915), Iowin (1918).

PROMISING NEW STRAINS

Russian.

Present work—Selections made from introductions and of standard and improved commercial varieties for high yield, stiff straw, winter hardiness, and rust resistance.

(15) KANSAS, Experiment Station, Manhattan:

Wheat Breeders:

Early workers—C. C. Georgeson, A. M. TenEyck, H. F. Roberts, S. C. Salmon.

Present workers—J. H. Parker*, C. O. Johnston*, A. F. Swanson* (at Hays), R. H. Painter.

Breeding Methods:

COMMERCIAL VARIETIES

Introduction (1882–1935):
Turkey.

Selection (1905–35):
Kanred (1917), *Blackhull, Clarkan.*

Hybridization (1912–35):
Kawvale (1931), Tenmarq (1932).

PROMISING NEW STRAINS

Hybridization:
Quivira (Prelude × Kanred).
Kanred × Hard Federation, C. I. 11373.

Present work—P 1066 × Marquis, to combine resistance to stem rust and winter hardiness of P 1066, with earliness, stiff straw, and excellent quality of Marquis. Kanred × Prelude, to combine resistance to stem rust and winter hardiness of Kanred, with earliness of Prelude. Kanred × Hard Federation, to combine resistance to stem rust, winter hardiness, and baking strength of Kanred, with earliness and short, stiff straw of Federation. Oro × Tenmarq, to combine bunt resistance and winter hardiness of Oro with earliness, stiff straw, high yield, and excellent quality of Tenmarq. Kawvale × Tenmarq, to combine resistance to leaf rust and Hessian fly of Kawvale, with the excellent quality of Tenmarq.

(16) KENTUCKY, Experiment Station, Lexington:

WHEAT BREEDER: E. J. Kinney.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction: *Fulcaster, Trumbull, Kawvale.*	
Selection (1912–35): Ashland (1915), Kentucky 47 (1918).	Kentucky 24-2.
Hybridization (1930–35).	

Present work—Crosses of Kanred with the best soft winter wheat varieties in Kentucky to obtain rust resistance and greater winter hardiness.

(17) MARYLAND, Experiment Station, College Park:

WHEAT BREEDERS:

Early worker—W. B. Hanger.

Present workers—J. E. Metzger, W. B. Kemp, R. G. Rothgeb.

BREEDING METHODS:

COMMERCIAL VARIETIES

Introduction:
Leap, Currell.

Selection (1907–35):
Mammoth Red (1914), Leapland (1924).

Present work—Pure-line selection of commercial varieties grown in Maryland.

(18) MICHIGAN, Experiment Station, East Lansing:

WHEAT BREEDERS:

Early worker—F. A. Spragg.

Present workers—E. E. Down, H. M. Brown.

BREEDING METHODS:

COMMERCIAL VARIETIES

Introduction (1899–1905):
American Banner (Dawson).

Selection (1906–35):
Red Rock (1913), (from natural cross in) Baldrock (1930).

Hybridization (1906–35):
Berkeley Rock (1922).

Present work—Crosses involving Berkeley Rock, Red Rock, American Banner, Minhardi, Early Windsor, and Trumbull. These varieties have been crossed not only among themselves but also on other strains which have desirable characteristics. Emphasis is placed on the production of high-yielding winter-hardy strains resistant to bunt and loose smut. Breeding both white and soft red winter wheats.

(19) MINNESOTA, Experiment Station, University Farm, St. Paul:

WHEAT BREEDERS:

Early workers—W. M. Hays, Andrew Boss, A. C. Arny, C. P. Bull, E. M. Freeman*, E. C. Johnson*, Alden A. Potter*, J. H. Parker*, R. J. Garber, O. S. Aamodt*.

Present workers—H. K. Hayes, E. C. Stakman, E. R. Ausemus*, R. H. Bamberg*.

Breeding Methods:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1888 1935): *Marquis, Ceres.* Selection (1902–35): Haynes Bluestem, Minn. 169 (1899), Glyndon Fife, Minn. 163 (1899), Mindum (1917). Hybridization (1902–35): Hard red winter: Minturki (1917). Soft red winter: Minhardi (1917). Hard red spring: Marquillo (1929). Thatcher (1934).	Hybridization: Winter: Minturki × Marquis, Minn. 2616, C. I. 11501. Minard × Minhardi, Minn. 2313, C. I. 11656. Spring: Double-Cross, Minn. 2315, C. I. 10020. H-44 × Marquis, Minn. 2634, C. I. 11643.

Present work:

Winter wheat—crosses of Minhardi, Minturki, and Minard, with Marquis, Hope, and H–44 in yield trials to obtain hardy winter varieties improved in quality and resistant to stem rust. Segregates of backcrosses of Hope and H–44 × Minhardi and Minturki with Minturki to obtain high-yielding rust-resistant winter-hardy wheats.

Spring wheat—Marquillo, Thatcher, and other hybrid selections crossed with Hope and H-44 to obtain greater resistance to stem rust, leaf rust, and bunt. Backcrosses of Hope and H–44 types of resistance to Thatcher. Marquillo was withdrawn from the recommended varieties when Thatcher was distributed.

(20) MISSOURI, Experiment Station, Columbia:

Wheat Breeders:

Early workers—M. F. Miller, C. B. Hutchison, E. M. McDonald, L. J. Stadler, R. T. Kirkpatrick, W. R. Tascher.

Present worker—E. M. Brown.

Breeding Methods:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1922–35): *Red May, Fulcaster, Poole, Fulhio, Harvest Queen.* Selection (1906–35): Fulcaster Selection No. 8y (1912). Early May W2083 (1925). Michigan Wonder Selection No. 21 (1934).	Selection: Poole W308. Fulhio W1011. Harvest Queen W529.

Hybridization (1912–35).

Present work—Fulcaster, Michigan Wonder, Harvest Queen crossed Early May for combining earliness with high yield.

(21) MONTANA, Experiment Station, Bozeman.

Wheat Breeders:

Early workers—J. B. Nelson, H. R. Sumner, I. J. Jenson, M. A. Bell, H. N. Watenpaugh, LeRoy Powers, J. E. Norton, Austin Goth.

Present workers—L. P. Reitz (J. A. Clark*).

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1905–35): *Marquis*, Supreme (1924), *Federation*.	Reliance C. I. 7370.
Selection (1910–35): Montana No. 36 (1912).	Supreme Selection 640.
Hybridization (1921–35).	Yogo C. I. 8033. Hope × Marquis N. No. 1189, C. I. 11710.

Present work:

Winter wheat—varieties crossed include Ridit, Yogo, Oro, Minturki, and Albit for smut resistance; Yogo, Montana No. 36, Karmont, and Newturk for high yield; Albit for stiff straw; Montana No. 36 for quality; Quivira for earliness; Minhardi, Minturki, Yogo, and Buffum for winter hardiness.

Spring wheat—varieties crossed include Marquis, Supreme, Reliance, and Comet for high yield; Hope and Reliance × Hope, N. No. 1121, C. I. 11434 for bunt resistance; Hard Federation-Hussar, N. No. 1018, C. I. 11442, for near immunity from bunt, and short, stiff straw; Reward for high protein content and baking quality.

(22) Judith Basin Branch Station, Moccasin:

WHEAT BREEDERS:

Early workers—E. L. Adams*, N. C. Donaldson*, R. W. May*, B. B. Bayles*.
Present workers—J. L. Sutherland* (K. S. Quisenberry*).

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1909–35): *Marquis*, *Supreme*.	Canus (Canada).
Selection (1909–35): Karmont (1922).	
Hybridization (1920–35): Newturk (1927). Yogo (1933)	Eureka × Minhardi, C. I. 8036. Hard Federation × Hussar, N. No. 1018, C. I. 11442.

Present work:

Winter wheat—varieties crossed include Karmont, Newturk, Yogo, for high yield; Oro and Ridit, for bunt resistance; and Minhardi and Minturki for winter hardiness.

Spring wheat—varieties crossed include Hard Federation × Hussar, N. No. 1018, C. I. 11442, Marquis, Reliance, Hard Federation, Comet, Hope, and others to combine characteristics of high yield, bunt resistance, earliness, stiffness of straw, and high quality.

(23) Northern Montana Branch Station, Havre:

WHEAT BREEDERS: M. A. Bell (J. A. Clark*).

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1916–35): *Marquis*, *Supreme*.	Baart.
Selection (1924–35): *Montana No. 36*, *Karmont*	Supreme, Havre Selections 59 and 66.
Hybridization (1924–35).	Comet (Marquis × Hard Federation). Turkey × Minessa, C. I. 8028.

Present work—Cooperative spring wheat breeding work with the Division of Cereal Crops and Diseases resulted in Comet. Recent crosses, Comet × Reliance-Hope, N. No. 1121, Baart × Reliance-Hope, N. No. 1131, and Baart × Hard Federation × Hussar, N. No. 1018 for earliness, high yield, drought resistance, high protein content, and other qualities.

(24) NEBRASKA, Experiment Station, Lincoln:

WHEAT BREEDERS:

Early workers—T. L. Lyon, Alvin Kezer, E. G. Montgomery.

Present workers—T. A. Kiesselbach, C. A. Suneson*.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1900-1926): *Ceres.*	
Selection (1902–35): Nebraska No. 60 (1918). Cheyenne (1930).	Turkey Selection Nebr. No. 1069, C. I. 10016.
Hybridization (1903–35): Nebraska No. 28 (1910).	Oro × Fulhard, C. I. 11579. Kawvale × Tenmarq, C. I. 11669.

Present work—Hussar, Oro, Minturki, Turkey Selections, C. I. Nos. 10115, 10016, 11576, and 11577, Oro × Fulhard, C. I. 11579, Tenmarq × Minturki, C. I. 11580, and Yogo crossed on standard and other varieties for bunt resistance. Blackhull, Kawvale, and Cheyenne crossed on Nebraska varieties for Hessian fly resistance; Nebraska No. 28, Turkey, C. I. 10016, and Quivira for early maturity; Iowin, Kawvale, and Hope for leaf rust resistance; Minhardi, Minturki, and Lutescens for cold endurance. Standard local varieties as Cheyenne, Nebraska No. 60, Nebraska No. 6, and Kanred have been used for crossing with the above varieties because of their known yield.

(25) NEW JERSEY, Experiment Station, New Brunswick:

WHEAT BREEDERS:

Early workers—R. E. Blaser, E. E. Evaul, N. F. Farris, W. G. Colby, Norman Curtis.

Present workers—H. B. Sprague, M. E. Paddick, G. W. Burton.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1923–35): *Leap, Poole, Dawson.*	Eleven selections of commercial varieties and 18 selections of hybrids are under an advance test in 1935 to determine the ones most superior.
Selection (1930 35).	
Hybridization (1924-35).	

Present work—Kanred × Fultz, Kanred × Dawson, Kanred × Nittany, to combine tillering ability and grain quality with adaptation of the soft parents, and resistance to eastern wheat diseases.

(26) NEW YORK, Experiment Station, Ithaca:

WHEAT BREEDERS:

Early workers—H. J. Webber, F. J. Pritchard, E. P. Humbert.

Present workers—H. H. Love, W. T. Craig*, F. P. Bussell.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1907–35).	
Selection (1907–35): Honor (1907), Forward (1912), *Junior No. 6* (Goldcoin).	
Hybridization (1913–35): Valprize (1913).	Dietz selection × Goldcoin selection.

Present work—Honor × Forward, Honor-Rosen (rye) × Honor, and other crosses between varieties and species to produce better yielding varieties, commercially desirable. White winter wheats are preferred.

(27) NORTH CAROLINA, Experiment Station, Raleigh:

WHEAT BREEDERS:

Early workers—R. Y. Winters, G. M. Garren.

Present workers—P. H. Kime, W. E. Adams.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction: *Leap*, *Fulcaster*, *Purplestraw*, *Redhart*.	Selection: Fulcaster selection No. 151.
Selection (1915–35): Leap No. 12, Leap No. 32 (1920).	Hybridization: P–1068 × Fulcaster 2030–2–51–5.
Hybridization (1928–35).	

Present work—Crosses involving Fulcaster, Leap, Purplestraw, Turkey strains, Gladden, and Grandprize, made to combine high yield with resistance to leaf rust.

(28) NORTH DAKOTA, Experiment Station, Fargo:

WHEAT BREEDERS:

Early workers—W. M. Hays, J. H. Shepperd, H. L. Bolley, O. W. Dynes.

Present workers—L. R. Waldron, G. S. Smith*.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1900–1935): Kubanka (1902), *Marquis*, Pentad (1911), Monad (1913).	Selection: Kubanka 49.
Selection (1887–1935): Power Fife (1892), Kota (1920).	Hybridization: Marquis × Kota Ns. 1656.106, C. I. 11468. Ceres × Hope-Florence Ns. 2553, C. I. 11640. Ceres × Hope-Florence Ns. 2592, C. I. 11712.
Hybridization (1917–35): Ceres (1926), Komar (1931).	

Present work—Ceres × Hope-Florence selections, including the above are most promising for yield, drought resistance, green-leaf area, resistance to stem rust, leaf rust, loose smut, bunt, and of high quality for milling, protein content, color of flour, and texture and volume of loaf. Komar-Hussar × Ceres, Hard Federation-Hussar N. No. 1018 × Hope-Ceres N. No. 1098 and other crosses combining the near-immune reactions from both stem rust and bunt in one cross.

(29) Northern Great Plains Field Station, Mandan:

WHEAT BREEDERS:

Early workers—E. R. Ausemus*, V. C. Hubbard*.

Present workers—(J. A. Clark*), J. C. Brinsmade*.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Hybridization (1922–35):	
Reliance (1926).	Reliance × Hope, N. No. 1121, C. I. 11434. Ceres × Hope, N. No. 1226, C. I. 11683.

Present work—Ceres × Hope, Hope × Marquis, Reliance × Hope, and many other crosses, backcrosses, and multiple crosses, involving Hope and H–44 wheats for near immunity from stem rust, resistance to drought, and high protein content of grain.

(30) Dickinson Substation, Dickinson:

WHEAT BREEDERS:

Early workers—L. R. Waldron, J. A. Clark*.

Present worker—R. W. Smith*.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1908–35). Selection (1910–25): Nodak (1920). Hybridization (1912–35)	Selection: Kubanka 132. Hybridization: Kanred × Buffum, C. I. 8030. Komar-Hussar, C. I. 11685. Hope × Turkey-Florence, C. I. 11711.

Present work:

Spring wheat—crosses and backcrosses of Hussar, Martin, Ridit, and Turkey-Florence with Komar, Ceres, Reliance, Hope, Marquis, and other wheats for bunt and drought resistance.

Winter wheat—crosses involving Turkey and Kanred with Minhardi and Buffum for winter hardiness, and Yogo and Oro for bunt resistance.

(31) Langdon Substation, Langdon:

WHEAT BREEDERS: G. S. Smith* (J. A. Clark*).

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1929–35). Hybridization (1930–35).	Hybridization: Durum: Mindum × Monad, A-2-4-2-02. Mindum × Kubanka 132, A-1-2-2-02. Hard Red Spring: Hope × Ceres, N. No. 1098, C. I. 11428. Reliance × Hope, N. No. 1110, C. I. 11433.

Present work:

Durum wheat—crosses of Mindum, Kubanka, Akrona, Nodak with Pentad, Monad, and Kubanka 132 for rust resistance. Mindum × Vernal (emmer) backcrossed with Mindum for near immunity from stem rust in durum wheat. Mindum and Kubanka used in many durum crosses and backcrosses for high quality of semolina and macaroni.

Hard red spring wheat—crosses of Comet × Hope-Ceres, N. No. 1098, and Comet × Reliance-Hope, N. Nos. 1110 and 1121, for early maturity, rust, drought and bunt resistance, and high yield.

(32) OHIO, Experiment Station, Wooster:

WHEAT BREEDERS:

Early workers—J. F. Hickman, G. G. Williams, L. E. Thatcher.

Present workers—C. A. Lamb, L. E. Thatcher, J. B. Park.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Selection (1904–30): Trumbull, Gladden, and Portage (1916), Fulhio (1918), and Nabob (1928). Hybridization (1915–35).	Selection: Ohio 9920. Hybridization: Portage × Fulcaster T. N. 1006. Gladden × Trumbull T. N. 1029. Ohio 9920 × Dawson T. N. 1055.

Present work—Some of the more important crosses are among Trumbull, Fulhio, Fultz, Poole, Fulcaster, Portage, soft wheats, crossed with Ridit, Hussar, Minhardi, Minturki, Malakof, and Kanred for resistance to bunt and winter injury.

(33) OKLAHOMA, Experiment Station, Stillwater:

WHEAT BREEDERS:

Early workers—A. Daane, Fred Griffee.

Present worker—C. B. Cross.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1930-35): *Turkey, Blackhull, Kanred, Fulcaster, Harvest Queen, Denton.*	
Selection (1930-35): Sibley No. 81 (1916). Sibley No. 62 (1917).	Penquite selection.

Present work—Selection of commercial varieties grown in Oklahoma and of introductions and hybrids obtained from neighboring States and from the United States Department of Agriculture.

(34) Southern Great Plains Field Station, Woodward:

WHEAT BREEDERS:

Early worker—Edmund Stephens*.

Present workers—V. C. Hubbard*, (K. S. Quisenberry*).

BREEDING METHODS:

COMMERCIAL VARIETIES

Introduction (1930–35).
Selection (1931–35).
Hybridization (1931–35).

Present work—Hope × Blackhull, Turkey × Kanred for rust resistance. Various white wheats such as Arco selections, Hybrid 128, Goldcoin, etc., have been crossed with Hard Red Winter wheats to obtain stiff straw, and short, early types of plant. Ridit × Quivira, Oro × Cheyenne, and Martin × Blackhull backcrosses on Blackhull for bunt resistance. Early Blackhull and Nebraska No. 28 crosses on Cheyenne, Kharkof, Kanred, etc., for earliness and drought resistance.

(35) OREGON, Experiment Station, Corvallis:

WHEAT BREEDERS:

Early workers—C. C. Ruth, H. M. Woolman, E. N. Bressman.

Present workers—G. R. Hyslop, D. D. Hill.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1909–35): Wilhelmina (Holland, 1910), *White Winter, Rink, Jenkin, Marquis, Huston, Oregon Zimmerman.*	Selection: Union (Oregon No. 16). Oregon No. 154 (Red Chaff selection).
Selection (1920–35): Hood (1932).	
Hybridization (1918–26).	

Present work—Hussar, Martin, and Hohenheimer for bunt resistance, crossed with each other.

(36) Sherman County Branch Station, Moro:

WHEAT BREEDERS:

Early workers—H. J. C. Umberger*, F. J. Schneiderhan*, B. B. Bayles*.

Present workers—D. E. Stephens*, R. B. Webb*.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1912-35): *Turkey*, *Baart*, Federation and Hard Federation (1920).	
Selection (1912-35): Oro (1927), Rio (1930).	Golden (Goldcoin).
Hybridization (1916-35): Sherman (1926), Rex (1933).	Arco (Arcadian × Hard Federation). Imbler (Goldcoin × Hybrid 128).

Present work—Arcadian × Hard Federation and Goldcoin × Hybrid 128 crosses for short stiff straw, club wheats. Goldcoin × Federation for earliness and short stiff straw. Rio, Oro, Turkey Selection, C. I. 11376, and Turkey-Florence crossed with each other to combine resistance to several forms of bunt. Goldcoin × Hybrid 128 strains crossed with Oro, Rio, Turkey Selection, C. I. 11376, and Turkey-Florence for bunt resistance, stiff straw, winter hardiness, and earliness in club types with white grain.

(37) Pendleton Field Station, Pendleton:

WHEAT BREEDERS: J. F. Martin.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1930-35).	Hybridization:
Hybridization (1930-35).	Goldcoin × Hybrid 128, C. I. 11700. White Odessa × Hard Federation, C. I. 10065.

Present work—Federation, Goldcoin-Federation, Rex, and Triplet crossed with Oro and Turkey-Florence for bunt resistant, early winter-hardy strains with white grain.

(38) PENNSYLVANIA, Experiment Station, State College:

WHEAT BREEDERS:

Early worker—C. F. Noll.

Present workers—C. J. Irvin, H. B. Musser, C. O. Cromer, C. F. Noll.

BREEDING METHODS:

COMMERCIAL VARIETIES

Introduction:
Forward, *Leap*.

Selection (1909-35):
Nittany (1909).

Hybridization (1910-35).

Present work—Soft winter varieties crossed with Nittany for higher yields, stiffer straw, and quality for both bread and pastry flour. Crosses between soft winter varieties and Turkey (C. I. 1571), Sherman, Ridit, and Hussar for resistance to bunt. Crosses with Fulhard, and Kawvale for resistance to Hessian fly.

(39) SOUTH CAROLINA, Coker's Pedigreed Seed Co., Hartsville:

Wheat Breeders:

Early worker—H. J. Webber.

Present workers—J. B. Norton, R. S. Cathcart, G. J. Wilds.

Breeding Methods:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Selection (1916–35): *Redhart.* Hybridization (1920–35).	Hybridization: Redhart × Golden Chaff, Sta. 2. Redhart × Golden Chaff, Sta. 3.

Present work—Redhart × Golden Chaff, Kanred × Redhart, Redhart 3 × Georgia Red, Redhart 3 × Leap, etc., to combine earliness and high yield.

(40) SOUTH DAKOTA, Experiment Station, Brookings:

Wheat Breeders:

Early workers—D. A. Saunders, J. S. Cole*, M. Champlin*.

Present worker—K. H. Klages.

Breeding Methods:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1901–35): Kubanka (1902), *Marquis, Reward, Mindum, Turkey, Minturki.*	
Selection (1915–35): Acme (1914).	Kubanka 75 3 15.
Hybridization (1929–35).	

Present work—Hard red spring wheats × Marquis emmer, and double crosses; hard red winter wheats × Buffum; and durum wheats, Kubanka × Algeria for rust and drought resistance.

(41) United States Field Station, Redfield (discontinued, 1935)

Wheat Breeders: E. S. McFadden* (transferred to College Station, Tex.).

Breeding Methods:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Hybridization (1929–34): Hope (1926).	H–44, C. I. 8177. H–44 × Marquis, C. I. 11551, Selection 1552. Kota × Webster, H–209, C. I. 11463.

Present work—Kota × Webster crosses for rust, heat, and drought resistance. Hope and H–44 crossed with Marquis, Ceres, and Kota-Webster strains, for resistance to stem rust, leaf rust, bunt, loose smut, drought, and heat. Species hybrids including different classes of wheat with native species of *Agropyron.*

(42) TENNESSEE, Experiment Station, Knoxville:

Wheat Breeder: C. D. Sherbakoff.

Breeding Methods:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Selection (1924–35).	Fulcaster No. 4, Leap No. 2, Mediterranean No. 80.
Hybridization (1930–35).	

Present work—Selections of Fulcaster, Fultz, and Leap superior for yield and disease resistance, have been crossed among themselves for further improvement.

(43) TEXAS, Substation No. 6, Denton:

Wheat Breeders:

Early workers—A. H. Leidigh, C. H. McDowell.

Present workers—P. B. Dunkle (P. C. Mangelsdorf), I. M. Atkins*.

Breeding Methods:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1910–35): *Mediterranean, Turkey, Kanred, Blackhull, Tenmarq.*	
Selection (1916–35): Denton (1926).	Mediterranean Selection No. 81.
Hybridization (1925–35).	

Present work—Denton, Clarkan, Kanred, C. I. 3015-63, Hope, Tenmarq, Hussar, and Fulcaster used for crossing to combine productiveness with disease resistance in strains of both soft red winter and hard red winter wheats. Hope × Mediterranean Selection No. 63 crossed on commercial wheats for rust resistance; Clarkan, for stiff straw; Blackhull, for non-shattering.

(44) UTAH, Experiment Station, Logan:

Wheat Breeders:

Early worker—George Stewart.

Present workers—D. C. Tingey, R. W. Woodward*, A. F. Bracken (at Nephi).

Breeding Methods:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1917–35): *Turkey, Federation.*	
Selection (1919–35): *Dicklow*, Utah Kanred (1928). Utac (1926).	Turkey 26.
Hybridization (1919–35): Relief (1931).	Hard Federation × Dicklow, Q 231-49. Ridit × Utah Kanred, 54a-1. Ridit × Utah Kanred, 54a-67.

Present work—Crosses of Dicklow, Federation, Hard Federation, Ridit, Utah Kanred, Hussar, Hope, Sevier, and Hohenheimer for high yield, strong straw, good quality, and resistance to loose and covered smuts.

(45) VIRGINIA, Experiment Station, Blacksburg:

Wheat Breeders:

Early workers: Lyman Carrier, T. B. Hutcheson.

Present worker: M. S. Kipps.

Breeding Methods:

COMMERCIAL VARIETIES

Introduction:
Fulcaster, Forward, Fultz, Leap.

Selection (1905–35):
V. P. I. 131 (1905), V. P. I. 112.

Present work—Selection of standard varieties.

(46) *Arlington Experiment Farm, Rosslyn:*

WHEAT BREEDERS:

Early workers—T. R. Stanton*, A. D. Ellison*, C. E. Leighty*.

Present workers—J. W. Taylor*, Wm. J. Sando*.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1907–35): *Purplestraw, Fulcaster, Fultz, Leap, Forward, Nittany.*	
Selection (1912–35): Shepherd (1923), Dixie (1931).	Arlando (Mammoth Red) T47–55.
Hybridization (1912–35).	Wharten (wheat-rye × Purplestraw).

Present work—Crosses of Berkeley Rock, Trumbull, Kawvale, Kanred, Genesee Giant, Fultz, and Illinois No. 2 for resistance to bunt, strong straw, softness of kernel, and winter hardiness.

(47) WASHINGTON, Experiment Station, Pullman:

WHEAT BREEDERS:

Early workers—W. J. Spillman, E. E. Elliott, Claude Lawrence, Alex Carlyle.

Present workers—E. F. Gaines, O. A. Vogel*, C. S. Holton*, O. E. Barbee.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1894–1935): *Turkey, Jones Fife, Pacific Bluestem, Baart, Federation, Oro, Jenkin.*	(Florence and White Track have been of value in breeding.)
Hybridization (1899–1935): Hybrid 128, Hybrid 123, and Hybrid 63 (1907), Hybrid 143 (1908), Triplet (1918), Ridit (1924), Albit (1927), Hymar (1934).	Jenkin × Ridit Wn. 2807, C. I. 10081.

Present work—Most outstanding crosses, Turkey × Hybrid 128, Turkey × Florence, Turkey-Pacific Bluestem × Turkey-Jones Fife, Turkey-Florence × White Odessa, Baart × Ridit, Marquis × Turkey, White Odessa × Hybrid 128, Pacific Bluestem × Hussar, Jenkin × Ridit, Florence × Marquis, Jenkin × Martin, Hybrid 128 × Martin, White Odessa × Turkey, Oro × Ridit, and Ridit × Hohenheimer. The principal objects are bunt resistance, white kernels, winter hardiness, yield, and quality of both soft (for pastry) and hard (for bread) wheats.

(48) WEST VIRGINIA, Experiment Station, Morgantown:

WHEAT BREEDERS:

Early workers—K. S. Quisenberry, M. M. Hoover.

Present workers—R. J. Garber, L. S. Bennett.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction: *Fulhio, Fulcaster.*	Reliable 80.
Selection (1921–35).	(Canada Hybrid) I–22–1125. Poole, I–22–1278.

Present work—Approximately 2,100 head selections from 19 commercial varieties were made in 1921. Some of these are still under trial.

(49) WISCONSIN, Experiment Station, Madison:

WHEAT BREEDERS:

Early workers—R. A. Moore, A. L. Stone.

Present workers—(E. J. Delwiche at branch stations), B. D. Leith, R. G. Shands*.

BREEDING METHODS:

COMMERCIAL VARIETIES	PROMISING NEW STRAINS
Introduction (1900-35): *Turkey*.	F. P. I. Nos. 94423; 94451; 94464.
Selection (1901-35): Wisconsin Ped. No. 2 (1906), Bacska (1908), Ashkof (1911), Progress (1916).	Four selections from Illinois No. 1.
Hybridization (1908-35): Sturgeon (1927).	

Present work—Varieties used in crosses: Minhardi, Minturki, Wisconsin Ped. No. 2, Turkey, Ashkof, Kharkof, Wis. 218, Beloglina, and Durabel for winter hardiness; Minturki, Progress, Hope, Marquillo, Kubanka, and Ceres for stem rust resistance; Fultz, C. I. 5308, and Kawvale for leaf rust resistance; and Bacska, Marquis, and Ceres for milling and baking quality.

(50) WYOMING, Experiment Station, Laramie:

WHEAT BREEDERS:

Early worker—B. C. Buffum.

Present workers—Glen Hartman, G. H. Starr.

BREEDING METHODS:

COMMERCIAL VARIETIES

Introduction (1920-35):
Marquis, Kubanka, Baart, Turkey, Kota.

Selection (1925-35).

Present work—Selections have been made from 46 standard varieties. Now testing the remaining strains for yield and bunt resistance.

Canadian Wheat Breeding Stations, Varieties, Wheat Breeders, and Present Work

[Varieties in italics are recommended for commercial growing but were not developed by the station Varieties in caps are now recommended for growing by the station. Asterisks indicate workers who have furnished reports.]

CANADA

ONTARIO—DOMINION DEPARTMENT OF AGRICULTURE:

(51) CENTRAL EXPERIMENTAL FARM, OTTAWA:

WHEAT BREEDERS:

Early workers—William Saunders, C. E. Saunders, A. P. Saunders.

Present workers—L. H. Newman, J. G. C. Fraser*, A. G. O. Whiteside.

BREEDING METHODS:

VARIETIES	YEAR DISTRIBUTED	SOURCE OR ORIGIN
Introduction:		
Ladoga	1888	Russia.
Red Fife	1890	Poland.
Selection:		
Early Red Fife	1908	Red Fife.
White Russian	1908	Do.

Varieties	Year Distributed	Source or Origin
Hybridization (1888–1935):		
Preston	1893	Ladoga × Red Fife.
Stanley	1893	Do.
HURON	1894	Ladoga × White Fife.
Percy	1894	Do.
Bishop	1894	Ladoga × Gehun.
MARQUIS	1908	Hard Red Calcutta × Red Fife.
Prelude	1913	Fraser × Gehun.
Ruby	1917	Downy Riga × Red Fife.
GARNET	1926	Preston A × Riga M.
REWARD	1928	Marquis × Prelude.

Present work—Breeding for early maturity. Crosses have not only been made between Garnet and Reward but between Reward and Bobs, Reward and Ceres, Reward and Supreme, Marquis and Garnet, etc.

(52) Agricultural College, Guelph:

Wheat Breeders:

Early workers—Thomas Shaw, C. A. Zavitz.

Present workers—R. Keegan, A. W. Mason, A. E. Whiteside.

Breeding Methods:

Varieties	Year Distributed	Source or Origin
Introduction:		
Dawson	1893	Robert Dawson, Paris, Ontario (farmers' selection).
Hybridization:		
O. A. C. 104	1917	Dawson × Bulgarian.

ALBERTA:

(53) University of Edmonton:

Wheat Breeders:

Early workers—G. H. Cutler, O. S. Aamodt.

Present worker—K. W. Neatby.

Breeding Methods:

Varieties	Year Distributed	Source or Origin
Selection:		
Renfrew	1926	Field hybrid.
RED BOBS 222	1928	Red Bobs.
Hybridization (–1935):		
Marquis, Reward, Garnet:		
CANUS	1934	Kanred × Marquis.

Present work—Breeding for bunt and drought resistance. Crosses between Canus (bunt resistant) and Reward; Canus and Prelude; etc.

(54) Experimental Station, Lacombe:

Present Wheat Breeder: George DeLong.

Breeding Methods:

Hybridization:

Garnet, Marquis, Reward and Red Bobs selections *Red Bobs 222, Supreme,* and *Early Triumph.*

Present work—Breeding for early wheats of good quality and yield.

BRITISH COLUMBIA:

(55) University of Vancouver:

Wheat Breeder: G. G. Moe.

MANITOBA:

(56) AGRICULTURAL COLLEGE, WINNIPEG, Dominion Rust Research Laboratory:

WHEAT BREEDERS:

Early worker—K. W. Neatby.

Present workers—C. H. Goulden*, R. F. Peterson.

BREEDING METHODS:

Introduction (1923–35):
Marquis, Reward, Ceres, Mindum.
Hybridization (1923–35):

VARIETY	YEAR DISTRIBUTED	SOURCE OR ORIGIN
RENOWN	1935	H–44 × Reward.

Present work—Breeding for stem rust resistance. Crosses include the rust-resistant varieties Pentad, Hope, H–44, Marquillo, Ceres, and Thatcher crossed with Marquis, Reward, etc. Promising new strains, Pentad × Marquis, R. L. 729; H–44 × Marquis, R. L. 704; H–44 × Reward, R. L. 716A.

(57) Experimental Farm, Brandon:

WHEAT BREEDERS:

Early worker—S. J. Sigfusson.

Present worker—R. F. Peterson.

BREEDING METHODS:

Hybridization.

Present work—Breeding for stem rust and drought resistance. Promising new strains, Hope × Reward C–26–1–9–2.

PRINCE EDWARD ISLAND:

(58) EXPERIMENTAL STATION, CHARLOTTETOWN:

PRESENT WHEAT BREEDERS: J. A. Clark, A. F. Tinney.

BREEDING METHODS:

Introduction: *Garnet, Huron, White Russian.*

Selection: From an old Island variety, producing Charlottetown No. 123.

QUEBEC:

(59) MACDONALD COLLEGE:

WHEAT BREEDERS:

Early workers: L. S. Klinck, G. H. Cutler.

Present workers: R. Summerby, Emile A. Lods.

BREEDING METHODS:

VARIETIES	YEAR DISTRIBUTED	SOURCE OR ORIGIN
Introduction:		
Huron, Marquis, Garnet.		
Selection (1907–12):		
KHARKOF M. C. 22	1912	Kharkof.
Hybridization (1914–35).		

Present work—Breeding spring wheat for yield of hay and grain. Varieties crossed include Pringles Champlain, Red Fife, Marquis, and Harrisons Bearded.

SASKATCHEWAN:

(60) UNIVERSITY OF SASKATOON:

WHEAT BREEDERS:

Early workers—G. H. Cutler, Manley Champlin.

Present worker—J. B. Harrington*.

BREEDING METHODS:

Introduction (1912–35):
Marquis, Ceres. Reward, Mindum recommended, and with reservations *Garnet, Reliance,* and *Supreme.*

VARIETIES	YEAR DISTRIBUTED	SOURCE OR ORIGIN
Selection (1914–35):		
Marquis Sask. 70	1927	Marquis Sask. 7.
Marquis Sask. 100	1932	Marquis Sask. 70.
Hybridization (1915–35):		
Redsask	1924	Red Fife × Bobs.
Planet (1929)		Red Fife × Bobs.
Croesus (1929)		Hard Red Calcutta × Taylors Wonder.
APEX (1935)		D. C. × H–44–Marquis.

Present work—Breeding hard red spring wheats for resistance to stem rust and drought. Crosses include Marquis, the early varieties Reward and Garnet; the rust resistant Hope and H–44, and the high yielding varieties Reliance and Thatcher. Promising new strains, A75 and A277 both from the H–44 D. C. × Marquis cross. These strains are both rust and smut resistant.

(61) EXPERIMENTAL STATION, SWIFT CURRENT:

PRESENT WHEAT BREEDER: H. J. Kemp.

BREEDING METHODS:

Hybridization:
Marquis, Reward, Red Bobs selections (*Red Bobs 222, Supreme,* and *Triumph*).

Present work—Breeding for sawfly resistance, using solid-stemmed varieties.

Wheat Breeding Stations, Directors, and Wheat Breeders in Foreign Countries

SOUTH AMERICA

ARGENTINA:

(62) Ministerio de Agricultura de la Nacion, Buenos Aires. Raimundo Nieves, head of the plant-breeding work.

(63) Institutio Fitotécnico de Santa Catalina, Universidad Nacional de La Plata. W. Rudorf, director; Klaus van Rosentiel.

(64) Bordenave Experimental Station of the Southern Railway, Bordenave, Buenos Aires Province. Carlos Munck, director.

CHILE:

(65) Estacion Experimental de la Sociedad Nacional de Agricultura, Casilla 40 D., Santiago. Manuel Elgueta*, chief.

(66) Servicio de Genética del Ministerio de Agricultura, Casilla 3873, Santiago.

(67) (Private breeder) Bernardo Wunder, Casilla 153, San Fernando.

PERU:

(68) Direccion de Agricultura y Ganaderia, Lima. Pedro Recavawen, director of agriculture.

(69) Comision Agronómica de Junin, Huancayo. César Fantaleán, Ingeniero.

(70) Comision Agronómica de Ancachs, Huarás. Senefelder Vallejos, Ingeniero.

AUSTRIA:

(71) Hochschule für Bodenkultur, Vienna. Erich Tschermak-Seysenegg, in charge of plant breeding.

(72) (Private breeders) Gustav Löw and Wilhelm Löw. Angern, Nied-Oesterreich.

BELGIUM:

(73) Institut Agronomique de l'État, Gembloux. V. Lathouwers, professor of genetics and plant breeding.

BULGARIA:

(74) State Agricultural Experiment Station, Obraztzov Tchiflik near Roustchouk. G. Proitcheff*, director; Khr. Dashkalov, plant breeder.

(75) University of Sofia. Dontcho Kostoff, agronomy, genetics, and cytology.

CZECHOSLOVAKIA:

(76) Technical University, Czech School of Agriculture and Forestry, Prague. Jaroslav Peklo*, professor (agricultural and forest phytopathology; genetics).

DENMARK:

(77) Agricultural College, University of Copenhagen, Genetics Laboratory, Rolighedsvej 23, Copenhagen. O. Winge, professor (genetics; cytology; fungi).

ENGLAND:

(78) University of Cambridge, Cambridge School of Agriculture, Cambridge. R. H. Biffen*, director of Plant Breeding Institute (genetics); F. L. Engledow, Drapers professor of agriculture (cereal genetics and breeding); A. E. Watkins, research assistant (genetics; cytology).

(79) University College, Reading. John Percival, professor of agricultural botany (cereals; *Aegilops*).

FINLAND:

(80) State Agricultural Experiment Station, Jokioinen, Suomi. Vilho A. Pesola, director of division of plant breeding (applied botany; plant breeding; cereals and grasses; ecology).

FRANCE:

(81) Station d'Amélioration des Plantes, Route de St. Cyr., Versailles:
Early workers: E. Schribaux, M. Maylin.
Present workers: L. Alabouvette* (genetic research), M. Ganneau, P. Jonard.

(82) University of Paris, Paris. Louis Blaringhem, professor of botany (genetics; physiology; biology).

(83) Vilmorin-Andrieux et Cie., 4 Quai de la Mégisserie, Paris (1°). Louis de Vilmorin (private breeder); Verrières-le-Buisson (S. et O.).

(84) Auguste Meunissier, Chef du Service expérimental de la Maison Vilmorin-Andrieux et Cie. Verrières-le-Buisson (genetics).

(85) Station d'Amélioration des Plantes de la C° des Chemins de Fer du P. L. M. Domaine du Prieuré d'Epoisses, Bretenieres par Longecourt (côte d'Or) Ch. Crepin, directeur.

(86) Station d'Amélioration des Plantes des Grande Culture, Clermont-Ferrand. M. Schad, directeur.

(87) University of Lyon, Lyon. Jean Beauberie, professor of botany (plant pathology).

(88) University of Toulouse, Toulouse. G. Nicolas, professor (agricultural botany).

(89) Tézier Frères, Valence-sur-Rhone (Drôme). Mlle. Marie Aline Dusseau, Chef de laboratoire (genetics).

GERMANY:

(90) Institut für Pflanzenbau und Pflanzenzüchtung der Universität Halle, Halle a. d. Saale, Ludwig-Wucherer-Str. 2. Theodor Roemer, director (agronomy; plant breeding); W. H. Fuchs (winter wheat); Kurt Hubert (rust resistance); P. Pelschenke (quality).

(91) Institut für Pflanzenzüchtung und Pflanzenbau Weihenstephan, Technische Hochschule, München, Freising (Bayern); Hans Raum (agronomy; plant breeding).

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(93) Institut für Landwirtschaftliche Botanik. Braunschweig-Gliesmarode, Braunschweig; W. Straib (rust resistance).

(94) Kaiser-Wilhelm-Institut für Züchtungsforschung, Müncheberg i. Mark. Ernst Oehler (*Triticum*).

GREECE:

(95) Experiment Station for Improvement of Plants, Salonika. J. S. Papadakis,* director (genetics).

HUNGARY:

(96) Agricultural Experiment Station for Plant Industry, Magyarovar. John Suranyi, agronomist.

(97) (Private breeder) R. Fleischmann, Rompolt.

ITALY:

(98) R. Stazione di Granicoltura, Rieti. Nazareno Strampelli, director (plant breeding).

(99) National Institute of Genetics As Related to the Cultivation of Cereals, Rome. Nazareno Strampelli, minister of agriculture.

(100) Stazione Sperimentale di Granicoltura, "B. Mussolina" per la Sicilia Via del Bosco 7, Catania. Ug de Cillis, director; R. Stazione Sperimentale Agraria Italiane, Modena.

(101) Alfonso Draghetti, director (agricultural botany). R. Instituto Superiore Agrario, Bologna; Francesco Todaro, professor (agriculture).

YUGOSLAVIA:

(102) Institut für Pflanzenzüchtung. Kgl. Univ. Zagreb. Alois Tavcar (genetics; plant breeding).

(103) Botanisches Institut, Universität König. Alexander I Ljubljana; Fran Jesenko, professor (physiology; genetics).

NETHERLANDS:

(104) Institut für Pflanzenzüchtung. Wageningen. A. E. H. R. Boonstra, botanist; H. Bleier (cytology; genetics; biology; plant breeding).

NORWAY:

(105) Teknologisk Institut. Oslo. Dipl. Ing. Lief Larson (quality).

(106) Experiment Station, Vidarohov, Hjellum. Haakon Wexelsen (agricultural plants, genetics).

POLAND:

(107) College of Agriculture, Warscawa (Warsaw). Edmund *Malinowski*, director (genetics).

(108) Skierniewice Institute of Genetics, Skierniewice. St. Jasuowski*.

(109) Lemberg Technical University, Laboratory of Plant Breeding, Dublany (near Lemberg). Kasimierz Miczynski, associate (genetics of *Aegilops* and wheat; cereal breeding).

(110) (Private breeder) A. Fanasz, Warsaw.

PORTUGAL:

(111) Ministry of Agriculture, Lisbon. Pedro C. Calderia de Castel-Branco, João de Carvalho e Vasconcellos.

RUMANIA:

(112) Samanta Society for Seed and Plant Selections, Cenad (Banat).

(113) Institului de Cercetari Agronomice. Stefan Popescu.

(114) University of Cluj, Academy of Agriculture, Cluj. N. Saulescu, professor (genetics; plant breeding).

SPAIN:

(115) Instituto Cerealicultura La Moncloa, Casa de Oficios, Madrid (8), Marcelino de Arana y Tranco (plant breeding). Fernando Silvela de Tordesilla.

SWEDEN:

(116) Swedish Seed Association* (Sveriges Utsädesforening), Svalof. N. H. Nilsson-Ehle, director; Hjalmar Nilsson; Gunnar Nilsson-Leissner (genetics; plant breeding); Åke Åkermann (physiology; plant breeding); Arne Muntzing (genetics; cytology).

(117) Kalmar Branch Station, Kalmar. O. Holmgren, superintendent

(118) Linköping Branch Station, Linköping. I. Walstedt, agronomist (plant breeding).

(119) Ultuna Branch Station. A. Elofson; R. Torssell.

(120) Weibullsholm Plant Breeding Institute*, W. Weibull, Ltd., Landskrona Birger Kajanus; S. O. Berg, agriculturist (plant breeding).

(121) Lund University, Lund. Artur Håkanson, professor (embryology; cytology).

SWITZERLAND:

(122) Swiss Experimental Station for Agriculture, Öerlikon-Zürich.
Early worker: A. Volkart, former director.
Present workers: F. T. Wahlen*, director; M. Buchli; S. Wagner.

(123) French-Switzerland Experiment Station, Lausanne-Mont Calme. Georges Bolens, director (Etablissement Fédérale d'Essais et de Contrôle de Semences).

UNION OF SOVIET SOCIALIST REPUBLICS:

(124) Institute of Plant Industry (Institut Rastenevodstvo), Leningrad. N. I. Vavilov*, director (genetics, applied botany, origin and geography of cultivated plants, immunity of plants); V. V. Talanov, second director, Institute of Applied Botany (agronomy); C. A. Flaksberger, professor, chief of wheat section, Institute of Applied Botany (classification and geography of the wheats of the world); Helen Emme, assistant, Institute of Applied Botany (phyto-cytology of cultivated plants); G. D. Karpetschenko, director, genetic laboratory, Institute of Applied Botany (genetics, genetic cytology).

(125) University of Leningrad, Leningrad. J. A. Filipchenko, professor (genetics).

(126) Odessa Genetic Institute, Odessa. A. A. Sapegin, professor of genetics and plant breeding, Agricultural College; director, Odessa Central Experiment Station (genetics; phylogenesis of wheat); L. A. Sapegin, Agricultural Experiment Station (genetics and cytology of the 28-chromosome wheat species).

(127) Agricultural Institute, Saratov. G. K. Meister, professor; director of the selection division of the Agricultural Experiment Station (genetics, selection, species hybridization, varieties); N. G. Meister, assistant in the selection division (selection, genetics, wheat-rye hybrids).

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CHINA:

(128) College of Agriculture and Forestry, Nanking. T. N. Shen.

(129) The National Agricultural Research Bureau, Ministry of Agriculture, Nanking. R. C. Shang, technical assistant.

INDIA:

(130) Department of Agriculture, Calcutta. A. Howard, lately director, Institute of Plant Industry, and agricultural advisor to State in central India and Rajputana, Indore. (c/o L. E. Matthaei, 9 Avenue Ernest Hentsch, Geneva, Switzerland.)

(131) Punjab Agricultural College, Lyallpur, Punjab. R. D. Singh, cerealist.

(132) Agricultural College, Poona, Bombay. B. S. Kadam, crop botanist to the Government (genetics of rice and wheat).

(133) Imperial Institute of Agricultural Research, Pusa. F. J. F. Shaw, director.

JAPAN:

(134) Kyoto Imperial University, College of Agriculture, Kyoto. H. Kihara, professor of genetics (cytology and genetics of plants); Ichizo Nishiyama (genetics, cytology); Shunjiro Wakakuwa (genetics).

(135) College of Agriculture, Morioka, Iwate-ken. Kiyomitsu Ryu.

(136) Hokkaido Imperial University, Sapporo. Tetsu Sakamura, plant physiologist (cytology).

(137) Nishigahara Noji Shikenjo, Takinokawa-mura, Kita-toyoshima-gun, Tokyo. H. Terao, chief, Division of Wheat Culture.

UNION OF SOVIET SOCIALIST REPUBLICS:

(138) Siberian Grain Institute, Omsk, West Siberia. N. V. Tzitzin.

(139) Polytechnic Institute, Tiflis, Georgia, Transcaucasia. L. L. Decaprelevicz, director of the selection division at the Botanic Garden (genetics; selection of agricultural plants; applied botany).

AFRICA

ALGERIA:

(140) Institut Agricole de Maison-Carrée, Alger. L. Ducellier, professor of applied botany (cereals).

EGYPT:

(141) Ministry of Agriculture, Cairo, Propagation Section:
Early workers: B. G. C. Bolland, M. El Dib Effendi, and G. P. Morris.
Present worker: James Philip*.

(142) Ministry of Agriculture, Giza. G. R. Morris, senior botanist (breeding of cereals).

KENYA:

(143) East Africa and Uganda Natural History Society, Coryndon Memorial Museum, Agricultural Department, Nairobi. C. J. L. Burton, plant breeder (genetics).

MOROCCO:

(144) Service de l'Agriculture et des Améliorations Agricoles, 67 Avenue de Temara, Rabat. Emil Miège, chef.

TUNISIA:

(145) Service Botanique et Agronomique de la Tunisia, El-Ariana près Tunis. F. Boeuf, director (applied botany; cereals).

UNION OF SOUTH AFRICA:

(146) Stellenbosch-Elsenburg College of Agriculture, Stellenbosch, Cape of Good Hope. J. H. Neethling, professor (genetics; plant breeding).

AUSTRALIA

FEDERAL CAPITAL TERRITORY:

(147) Commonwealth Council for Scientific and Industrial Research, Division of Plant Industry, Canberra. B. T. Dickson*, chief; Ref. J. R. A. McMillan*, senior geneticist.

NEW SOUTH WALES:

(148) Department of Agriculture, Box 36A, G. P. O., Sydney. H. Wenholz*, director of plant breeding.

(149) School of Agriculture, The University, Sydney. W. L. Waterhouse* (rust breeding); J. G. Churchward (smut breeding).

(150) Cowra Experiment Farm, Cowra:
Early worker: William J. Farrer.
Present workers: J. T. Pridham, plant breeder, and W. Curteis.

(151) Glen Innes Experiment Farm, Glen Innes. S. L. Macindoe; S. Smith-White.

(152) Temora Experiment Farm, Temora. B. Doman.

(153) Wagga Experiment Farm, Wagga:
Early worker: William J. Farrer.
Present worker: C. K. Vears.

(154) Grafton Experiment Station, Grafton. W. H. Darragh; W. Atkinson.

(155) Yanco Experiment Farm, Yanco. W. H. Pargendorff.

(156) Hawkesbury Agricultural College, Richmond:
Early worker: William J. Farrer.
Present worker: N. S. Shirlow.

QUEENSLAND:

(157) State Farm, Bungeworgorai. Via Roma. R. E. Soutlar.

(158) Gatton Agricultural College, Gatton. J. K. Murray.

SOUTH AUSTRALIA:

(159) Waite Agricultural Research Institute, Adelaide. A. E. V. Richardson, director. Department of Agriculture, Adelaide. A. J. Perkins, director.

(160) Roseworthy Agricultural College, Roseworthy. E. J. Breakwell*, plant breeder; A. R. Callaghan, principal.

(161) Waite Agricultural Research Institute (Federal), Glen Osmond. I. Phipps.

TASMANIA:

(162) Department of Agriculture, Hobart. F. E. Ward, director; A. H. Woodforde.

VICTORIA:

(163) Department of Agriculture, Melbourne. H. A. Mullett, director; I. Brake*, agricultural superintendent.

(164) State Research Farm, Werribee:
Early workers: A. E. V. Richardson (1911–24); H. Pye (1894–1931).
Present workers: George S. Gordon, cerealist; A. R. Raw, cereal geneticist; A. J. Vasey.

(165) Longerenong Agricultural College, Longerenong. I. M. Tulloh.

(166) Dookie Agricultural College, Dookie.

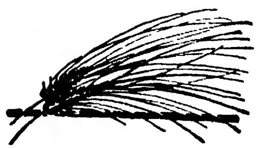
WESTERN AUSTRALIA:

(167) Department of Agriculture, Perth. G. L. Sutton*, director; Ref. I. Thomas.

(168) Merredin Experiment Farm, Merredin. Early worker: E. J. Limbourn (1919–32).

(169) Chapman Experiment Farm, Chapman. Early workers: C. Orchard (1913–21); D. R. Bateman.

Problems and Results in Barley Breeding



By H. V. Harlan, Principal Agronomist, and M. L. Martini, Assistant Botanist, Division of Cereal Crops and Diseases, Bureau of Plant Industry

BARLEY fields are found widely scattered over the more temperate parts of the world. They also form a picturesque part of the agricultural frontier. Barley fields occur in Europe, north of the Arctic Circle, and also on the plains of India. Barley is grown on the high plateaus of Tibet. It climbs still higher up the slopes of Mount Everest, where one form protects itself from the wind by a recurved stalk that places the heads almost on the ground. Barley is found fringing the oases of the Sahara or growing beneath the date trees. It is the crop that is grown highest up on the mountain peaks of Ethiopia, where pools of water are often frozen over beside the growing grain, and it is cultivated in the lower delta of the Nile, where brackish water lies 18 inches below the surface.

Arab farmers are seeding barley on the dry hills of Mariout along the Mediterranean in northwestern Egypt where the rainfall is but 8 inches, just as they were in the days of Rome, and Chinese peasants are growing age-old varieties in their western hills. Barley is cultivated by Hindus, Turks, and Japanese. It is grown by Russians, Berbers, and western Europeans. It is one of the grain crops of a hundred peoples throughout the temperate world. It is man's most dependable cereal where alkali, frost, or drought are to be encountered. Its greatest acreage, however, is found under more favorable conditions. It grows particularly well where the ripening season is long and cool. This is especially true in sections where the rainfall is high, for while it will stand much heat in the absence of humidity, it does not mature so well in hot humid weather. It grows better with moderate rather than excessive rainfall, better on well-drained lands than on water-logged or sandy ones.

Favorable conditions are found in our Northern and Western States. Our most extensive acreage is in the north Mississippi Valley and in California.

The Position of Barley in American Agriculture and the Chief Problems of the Breeders

IN THE United States, barley is most widely grown in the Northern and Western States. On well-drained soils not too sandy in character it produces more feed per acre than other small grains in these States. Much of the barley acreage is not in competition with corn, since it is grown north and west of the region where corn is the dominant crop. The trends for the past few years indicate a normal barley crop of around 300,000,000 bushels. The crops of the 2 years 1933 and 1934 are not a true measure of our production, for drought affected much of the barley area in both years

Barley has several natural advantages as a farm crop in the regions to which it is adapted. It produces a high yield per acre. It is early, and often escapes drought and usually is mature before rust becomes dangerous. It can be seeded later than other grains with better chances of success. It grows vigorously and usually smothers weeds.

Barley fits well into the agriculture of the north Mississippi Valley. The brewing demand affords a nearby cash market for the better qualities. The dairy industry uses a large amount of barley for feed. In those areas where the period available for spring work is short, it insures a fair production of feed on late-seeded ground. In the West it is the dominant feed grain. It grows well in such places as the interior valley of California and on the irrigated lands of the Rocky Mountain region. The importance of winter barley is increasing in the Southern States. Here it affords winter pasture when seeded for this purpose and the yield is fair where the crop is grown for grain. The barley acreage is probably smaller than it should be. Little of the present acreage devoted to barley could be used for any other small-grain crop without loss.

REGIONAL PROBLEMS IN BARLEY BREEDING

The major objectives of barley breeders are higher yield, malting quality, and convenience in handling. To attain these objectives many factors must be considered Low yield in one place may be due to lodging; in another to disease. Earliness may be important in one place and undesirable in another. Nonshattering varieties are essential where combine harvesters are used. Smooth-awned ones are desired by most farmers who harvest with a grain binder or use the crop for hay. A few farmers need varieties with special qualities. One may wish a variety that stools little, so that it will not grow too thickly, for use as a nurse crop, while another may wish one especially suitable for growing in high cold valleys where summer freezes are common. In other words, the problems of the various barley-growing sections must be studied separately, and these regional problems will be broadly surveyed here. We must also realize that in the future the requirements will become more and more specific, and these the plant breeder must meet.

Upper Mississippi Valley

In the Upper Mississippi Valley, much barley is grown primarily for malting purposes. When a maltster finds undesirable fungi spreading in his bins, or when a brewer has to start the pumps on a mass of unfilterable material in the mash tub, what does it mean? It traces back to the mistake of a buyer who this year is buying malting barley perhaps in northern Illinois, next year perhaps in South Dakota, searching always for the best for his purpose. Why is he forced to search? The reason lies mostly in the American climate that is favorable in varying localities in different years. In one season good barley can be grown well in the Corn Belt; in another, scab spreads rapidly on barley grown in the south on cornland and even finds conditions favorable far north, and then the maltster must be careful. In some years there is a long cool ripening period and the barley matures well and brewing supplies are plentiful. In other years drought or heat stops the maturing too soon, or storms lodge the crop and cause an interruption in the growth of many spikes. As a result, steely barley is in sight, and difficulty in brewing is sure to follow.

Such are the conditions that must be met. The plant breeders' problem is to produce varieties resistant to scab, that will lodge less easily, and that are as drought-resistant as is possible within the requirements of high yield in normal years.

Moreover, the farms of this section have become accustomed to smooth-awned barleys. In the future they will insist on new varieties being smooth. Over most of the area they will demand a malting variety. To most growers the chance of securing barley of premium grade for malting is sufficient to justify this choice. Indeed, it may be possible throughout the area to utilize malting varieties which will produce yields equal to those of the best feed varieties. That question is in the hands of the plant breeder. However, there is always a certain percentage of farmers who know at planting time that they will feed their whole crop. If feed varieties are available which are more satisfactory for their purpose than the malting sorts, some farmers will grow them.

Upper Plains

In the Dakotas and Montana the problem is complicated. A smaller percentage of the crop is likely to be used by the maltsters. Much of it is seeded on weedy land. The highest yields in many sections are produced by varieties not wanted by the maltsters. Droughts are frequent in the western Plains, and the farmer must choose between higher yield on the one hand and the chance of getting a market premium on the other. In the drier sections good yields in good years should be combined with the maximum insurance of some yield in bad years. The problems of the plant breeder are to combine quality and yield if possible, and, if not, to produce easily recognized varieties for the two purposes.

In the drier sections the best yields will be secured from early varieties, possibly from early varieties not entirely exserted from the boot; that is, the stalk ceases to elongate before the head is freed from the upper leaf and, therefore, the spike remains partially enclosed by it. But such varieties will not produce the highest yields in the better years, and at present there seems no way of combining the two

qualities. Most of the barley is certain to be used for feed in the average year, and the number of varieties under cultivation need not be as limited as in the regions where most of the barley purchased is used for malting. Wherever local conditions are diverse, a larger number of varieties are necessary to secure the maximum usefulness in an area. There are localities where the very earliest sorts are needed. There is another area in western North Dakota which appears to be better adapted to the production of two-rowed [1] sorts and one of the best varieties at present in Montana and parts of Wyoming is a two-rowed one.

Middle Plains

The only area in the central or southern Plains producing barley for market is centered about northwestern Kansas. This area is a peculiar one. The grain ripens in clear bright weather, usually with very little rain. The harvested grain has the general appearance of western barley. This is due not only to the ripening conditions but also to the fact that one of the common types, Stavropol, is very similar to the barleys grown on the west coast. Barleys of the Manchuria-Oderbrucker group are also grown. They, too, of course, are brighter than when grown in the more humid districts. In good years much of the crop may be sold to maltsters. The better lots of both Stavropol and Manchuria are sold for malting, but usually with preferences expressed by different buyers or even on different markets. Unless yield can be combined with quality and these with a type familiar to and desired by the malting trade, the situation must be met by the use of two or three varieties. The proportion of feed and malting types will vary with the premiums existing the previous season. Elsewhere in the middle and southern Plains where spring barley is grown, earliness and drought resistance are important.

Rocky Mountain Region

In the high mountain regions almost all varieties do well where irrigation water is available or where the natural rainfall is sufficient for the needs of the crops. In the hotter and more windy sections certain types, even though they grow well, cannot be used commercially as they shatter badly. In the cooler, better protected sections many varieties do well and are grown. Despite the fact that most barleys grow well, the breeding problems are very complex. Malting quality under irrigation is easily obtained, but feed in many sections is at such a premium that the feed demand is greater than the malting demand. Again, the region is made up of an endless number of units, each differing slightly from its neighbors in climate and economy, and often in farming practice. Over most of the world each mountain valley has eventually become a reservoir of safe keeping for a variety particularly adapted to that valley. Possibly that is the ultimate solution in America. At present the main problems are yield, resistance to shattering, resistance to lodging, and in some of the very cold valleys, resistance to summer frosts.

[1] Six-rowed barleys have three kernels at each node of the rachis and, since the nodes alternate, there result three rows on each side of the spike. Two-rowed barleys bear a single kernel at each node or single rows on each side of the spike.

FIGURE 1.—A barley nursery at Aberdeen, Idaho, where more than a thousand barleys are grown in short rows.

Pacific Coast

The European brewing market has been of great importance to west-coast barley producers for many years. This is particularly true of the California farmers. The use of varieties desired by the maltsters is essential. Shattering is one of the very important factors of yield. Two or three windy days in succession often have reduced the harvestable grain by half. Sometimes the winter rains come late. Seeding later than mid-January is often unsatisfactory unless quick-maturing varieties are used. Aside from the interior valley, there are many localities in California where barley is grown, and they differ from one another in their requirements. Situations like the Salinas Valley have long cool ripening seasons, and others like the Imperial Valley are characterized by early intense heat. The plant breeder has much to consider. His problems are not lessened in Oregon and Washington. The Willamette, the Klamath, and the Palouse are vastly different from one another. In the drier area of eastern Oregon and Washington, lodging is often caused by the failure of secondary roots to develop.

Southern Winter Barley Region

Winter barley is grown from Maryland to central Georgia and west to New Mexico. The total acreage is small. The situation is very complicated. True winter varieties are grown along the northern edge of the winter barley region. These extend on the higher lands into Georgia. Along the Coastal Plain and in the southern half of the region through Texas and New Mexico, varieties with less winter habit, or none, are often found. In Southern Arizona and California, spring varieties are seeded in the fall or winter for the entire crop. In Southwestern Kansas and adjacent areas, spring and winter seedings overlap.

The problems are endless. Greater winter hardiness is badly needed in Maryland, the Piedmont, southern Ohio, Oklahoma, north Texas, and Kansas. Yet the qualities that make for cold resistance are not the same in western Oklahoma as they are in Maryland or southern Ohio. Farmers who grow little barley object to rough awns. Throughout the South, smooth-awned or high-yielding hooded sorts are in demand. Yield will probably best be secured from the smooth-awned sorts. Winter dormancy in some localities needs to be separated from winter hardiness, as dormancy delays growth too much. At other places, dormancy is needed to prevent heading in warm periods before danger of freezing is over. Smut resistance is a very important factor in many places. As a result of lack of resistance to Hessian fly and chinch bugs, there is no winter barley in sections that appear favorable otherwise.

The Nature of Some Major Breeding Problems

ALTHOUGH the agronomic problems have been pointed out in this brief survey of breeding problems, a few merit more detailed treatment.

LODGING

Lodging may be caused by a number of factors. Stiffness of straw is the first objective of every breeder who endeavors to produce a barley that does not lodge. However, this does not necessarily mean stiffness. Many times slender tough culms or stems do not lodge any more than large, erect, stiff ones. The best parent is the one that lodges least regardless of the reason. A barley that lodges early is worse than one that lodges late. When there is early lodging, the development of the kernels is affected and the grain ripens unevenly. In some dry areas, secondary roots are not formed and the plant is not braced. Such plants lodge from the crown merely by toppling over. Other varieties are weakened by their susceptibility to diseases. Regardless of the causes, strains differ greatly and most barley breeders are choosing parents and making selections resistant to lodging.

WINTER HARDINESS

Winter barley is not so hardy as winter wheat or rye. It is more hardy than winter oats. The yields of winter barley are so large when it survives that there is demand for more hardy varieties along the northern edge of the winter barley region. There are inherent limitations in the plant itself that may prevent the development of a hardiness equal to that of wheat. In the Southeastern States, Tennessee Winter and Wisconsin Winter are the most hardy stocks. In western Oklahoma it is believed that other types probably arising from these are more resistant to the winter conditions of that region. In the Pacific Northwest the winter club types seem to possess the greatest hardiness. The problem of the breeder, then, has at least three divisions, on a geographical basis. At present he has nothing to start with but standard varieties.

YIELD

Yield is the sum of many factors. In one place it may depend on earliness; in another on resistance to disease or to lodging. At all places it is tied up with the intangible something we call vigor. No one knows why Trebi should produce high yields in areas not well suited to its growth and where it is subject to leaf infection and is too late for the best results. It is not clear why the Coast barleys adapted to the West do so poorly when grown in the upper Mississippi Valley. We do have a means of measuring the net results of adaptation, vigor, and disease resistance. Comparative yields can be determined by growing varieties in competition and weighing the grain. Every breeder is doing this and in table 1 (p. 338), showing breeding activities at the various stations, yield is not mentioned, for no breeder could release a variety which does not yield well. Much progress has been made in producing higher yielding sorts and the "recommended varieties" listed in table 4 (p. 345), are all satisfactory in this respect.

FEED

Most of our barley is destined to be used as feed. A surprisingly large proportion never leaves the farm on which it is grown. When a farmer grows feed for his own use, he is interested in but one thing securing the greatest possible amount of feed from an acre of land. Yield is of the highest importance. It makes little difference to most farmers whether or not the hull frays. It is only when barley is rolled that a good hull is needed in feed barley. Diastase is unimportant. Kernel size is immaterial except as it may affect the amount of hull where hogs are to be fed. The grower may not even know whether the market cares for his variety or not. Smooth awns are often desirable. It makes the handling of the crop easier and the straw more useful for feed and bedding. In some cases barley is grown for forage. Tillering or branching and large amounts of roughage are the ends sought. Here hooded or smooth-awned types are desired, although much of the rough-awned barley of California is cut for hay.

It is easier to produce a feed than a malting barley. Fewer factors have to be considered and high-yielding sorts have been produced at many of our experiment stations.

QUALITY

Quality, like yield, is affected by many factors, ranging from weather damage to chemical composition. Some of the factors fall in the breeders' province. Mellowness, the most intangible feature of quality, is largely dependent on the fitness of the variety to the region in which it is grown. When starch is formed in the kernel, there are many intermediate products. These halfway materials constitute a large percentage of the solids of the kernel in the early stages of growth. As the kernel develops these products constitute less and less of the total weight and in a fully mature and well-ripened kernel, they are negligible. Any barley kernel in which growth is interrupted will be "steely", that is, hard, with small-sized starch particles and intermediate products that dry down to a flinty mass. Such inter-

ruptions may come from disease, from drought, or, in humid climates, from hot weather. A barley that is well adapted to the section will avoid the bad effects of such adverse conditions better than one not well adapted. The varieties of the Pacific coast when grown in the West develop large starchy endosperms and are low in protein. The midwestern varieties when grown on the Pacific coast are lower in protein than when produced farther east, but in good years mellow barley is common in the upper Mississippi Valley.

Diastatic power is a measure of the ability of the kernel to convert starch to malt sugar. Some barleys have enough diastase to convert readily much more starch than is contained in the kernel. Most brewers desire such barley. Good diastatic power is partially dependent on the size of the kernels and it is relatively greater in the smaller kernels. Large-kerneled barleys, such as Coast, Atlas, and the two-rowed sorts, have a large starch endosperm. The scutellum, the part of the embryo which secretes the diastase, is little larger than that found in the smaller kerneled barleys. Naturally, then, such small-kerneled varieties as Oderbrucker and Manchuria, particularly as grown in the upper Mississippi Valley, are relatively richer in diastase.

All brewers desire a firm hull that is well attached to the kernel. Loosely attached hulls skin and fray, and, hence, do not make attractive malt, with the desired firm hull. The smooth-awned sorts are prone to have loose hulls. There is no reason known why well-attached hulls cannot be obtained in smooth-awned barleys.

Protein content is partly varietal and partly regional. Much of the protein is in the embryo and in the thin layer just beneath the hull, called the aleurone layer. In small-kerneled barleys these constitute a greater percentage of the total seed than they do in large-kerneled barleys. Both embryo and aleurone survive the brewing process and are found in the brewers' grains. Barley grown on rich land contains more protein than barley grown on lands of moderate fertility. Thin barley has more protein than plump barley. Barley grown in the humid areas contains a higher percentage of protein than barley grown in the West.

The breeder's avenue to quality is to produce barleys well adapted to the region—barleys that will mature well and will not lodge. Malting barley should be resistant to diseases. For our malting trade, small-kerneled barleys are important and easily obtained. The western export trade demands a larger kernel and the breeders of that section have suitable parental material at hand. In the smooth-awned varieties, selection for a tighter hull will not only better satisfy the maltster but will likely reduce the infection from loose smut as well.

COLOR

Barley may be white, black, red, purple, or blue. The latter three colors are due to anthocyanin pigments, and when these pigments occur in the barley hulls, they are red or purple, but when they occur in the aleurone layer, they are blue. The white and blue varieties are the only ones grown extensively in the United States.

Blue barley has a peculiar status at the moment. In the upper Mississippi Valley the color is often considered an index of steeliness. This opinion persists despite the fact that the blue O. A. C. 21 of

Canada is fully satisfactory to those Canadian brewers who wish a six-rowed barley. It persists despite the fact that the only American barley that is bought at a premium on the English market is the blue barley of the Pacific coast. Indeed, when Atlas was introduced many English buyers complained that it was not blue enough. The breeder, then, is confronted with local market prejudices. An infinitesimal amount of a harmless pigment in a layer of tissue that is not modified in brewing may add one more factor that he must consider in breeding malting barley. We have many varieties of both blue and white barleys, and if it must be done, we can meet the market requirements.

DISEASE RESISTANCE

The survey of superior germ plasm in barley made for the 1936 Yearbook included inquiries as to the relative importance of diseases in the different States. In general, the replies showed the major problems to be limited to the effects of a few organisms. Because artificial epidemics in all cases cannot be obtained with uniformity, resistance cannot be fully studied and the point of attack is not always clear. It is necessary for the breeder to have a method of testing his strains for resistance to specific organisms before he can transfer the desired characters to his better barleys. The technique of inducing artificial epidemics is not equally advanced in all cases, and the status is indicated in the following discussion of the various diseases.

FIGURE 2.—R. A. Moore, identified with the early testing of varieties and the breeding of Oderbrucker.

Scab is a serious disease in the Mississippi Valley. It is particularly bad on cornlands and heavy, poorly drained soils. It becomes more and more serious as barley growing is pushed southward into the hotter parts of the Corn Belt. In northern and western sections of the valley it decreases much as does the cultivation of corn itself. Its presence is ruinous to malting quality. It also makes the grain unsuited for feeding to hogs or horses, but it can be used for cattle and poultry.

Breeding for scab resistance is partially solved. Covering areas with cloth helps to induce high infections so that resistance can be studied effectively. This method is used at at least two stations. While evaluation of quantitative infection in plants that vary in leafiness and earliness is necessarily difficult, the present hope of obtaining scab resistance lies in using this procedure.

Covered smut is of more importance than loose smut. The latter seldom reaches high percentages. Loose smut is likely to be worse on smooth-awned varieties. As the teeth from the awns are re-

moved, the hairs on the stigma are eliminated. This impedes fertilization and more flowers stand open until outside pollen effects fertilization. Loose smut spores may enter during the time the flowers are open. Both covered and loose smut exist throughout the barley-growing regions, but their importance varies from place to place. Breeding for smut resistance in barley has hardly commenced. Uniform artificial infections are difficult to secure and while progress is being made, a more dependable method of testing would be very welcome.

Stripe, like the smuts, is found more or less throughout the barley area. It is unimportant in market grain as kernels from plants affected by stripe seldom appear in the threshed grain. Its field importance, from the standpoint of reducing yield, is difficult to estimate. The percentage of plants killed is usually low, and where this is the case the plants die so early that their neighbors by using the space must compensate for much of the loss of stand. Recently a method of securing high infections of stripe has been developed and breeders are now able to test their progenies effectively for resistance.

Scald is practically limited to the Pacific coast. As with all leaf infections, it is difficult to appraise the actual damage.

Mildew is most common on the North Pacific coast and in the southeastern barley region. Infections are easily secured in the greenhouse and strains of barley vary in their resistance.

Foot rot (*Helminthosporium sativum*) is a serious seedling disease in the upper Mississippi Valley. Over a period of years it is probably the most serious disease of barley in this region. It is found throughout the United States but is less frequently serious elsewhere.

The technique of artificial inoculation is satisfactory for breeding purposes, and such varieties as Glabron and Velvet were subjected to foot-rot infections during the stages when selections were being made.

Blight is a term used to designate blackened kernels. It is caused and intensified by many different organisms. It is particularly important in malting barley, where the situation is complicated by the difficulty of distinguishing the effect of scab from other organisms that discolor kernels. The farmer is likely to lose by marketing blighted barley. His particular sample may be free from scab and thus be perfectly satisfactory for feeding purposes, but the buyer, being unable to determine the exact nature of the blighting, must discount the price.

. Since blight is a market term, it means nothing to the breeder. The causes must be attacked separately, and the minor infections will probably not enter the field of breeding activities in the near future.

PRESENT ACTIVITIES OF BREEDERS

Many problems of barley breeding are recognized. Others will become apparent from time to time. Problems and breeding activities are perennial. The solution of the problems we now see will require much time. The full force of plant breeding cannot be focused on barley. In many States it is a secondary crop. Even in the barley States, the personnel and funds available for breeding work are limited. The breeders often have other crops to look after and they must divide

their efforts as seems most advisable. Even where barley breeding is a major project, the breeder has to choose among the many things to be done. The amount of work at any station varies from time to time.

The Desirable Characters, Acreage, and History of Superior Varieties of Barley (p. 330) has been prepared in an effort to show which phases of the barley-breeding problem as a whole are under consideration at the various stations at the present time. At many stations, it will happen that the number of lines now being considered is less than has been the case at some previous period. However, the summary does picture existing activities and it will doubtless be useful to breeders working on the same problem.

Methods Used in the Breeding and Testing of Improved Varieties

BARLEY is a self-fertilized or close-fertilized grass. Usually the flowers are pollinated before the spike emerges from the boot. In many sections field hybrids are rare. Even where cross-pollination takes place, the resultant variations become homozygous within a few generations through self-fertilization. Breeding methods are based on the presumption that a homozygous strain will produce the same kind of barley as long as it is grown. Where the fields are pure this assumption seems to be sound for practical purposes. Fields of Trebi in southern Idaho, where the chances of mechanical admixtures are remote, show no plants that vary in height or type from the rest of the field. New varieties are based on the selection of single plants that differ in some way from the varieties already at hand. These variants may be ones already existing in fields or in introduced populations, or they may be induced by hybridization.

FIELD SELECTIONS

The earlier barleys grown in North America consisted of a large number of similar types. Some of our best barleys have come from plants found by careful inspection of fields of these varieties. For example, Atlas is a selection from the Coast barley of California. In this case a large number of selections were made and grown for comparison by the usual methods of nursery testing. Selections such as these are homozygous and need only to be increased to constitute new varieties.

The same procedure is commonly practiced with importations from foreign countries. Many of these are bulk lots from remote districts in Asia and Africa. They are mixed as were our early varieties. They are first grown under detention to be sure that no disease is introduced with them. If free from disease, plant selections of the various types are made and tested. Trebi, Horn, and Peatland are examples of varieties which have originated in this way.

Most of the recent activities in barley breeding involve hybridization. Varieties of barley are easily crossed by artificial methods. The method of handling the hybrid populations depends considerably on the end to be attained. If the breeder is concerned with the production of a good barley and has no variety at hand that is outstanding, he may start on a large scale. In such cases the choosing of parents is difficult. Often the most logical cross has some inherent factors that make it unsatisfactory. On the other hand, barleys not very highly regarded may produce the offspring he is looking for. To insure a satisfactory combination, many crosses are sometimes made. One barley-breeding project now well advanced involves more than 400 separate combinations.

Once the hybrids are made, the problem is to find the desirable progeny lines. Several methods are in use. Some breeders select promising plants in the F_2 generation. These lines are reselected each year until superior homozygous strains are obtained. Other breeders prefer to grow the hybrids in bulk for a few generations before selections are made. The theory back of this procedure is that it allows natural selection to eliminate some of the weaker lines. It also affords time for the progeny lines to become homozygous. The need for reselection is consequently reduced and the total amount of labor is much less. A larger number of crosses can be carried through this stage on no greater funds. A third method is to bulk many hybrids together in a field plot and reseed each year from machine-run grain harvested from the plot. This is the least expensive of the three methods. Of course, the record of the parentage of any varieties produced in this way is lost, if that is important. The relative value of the three methods is unknown. The fact that all three are in use is evidence that breeders do not agree. One extensive experiment is under way where 7,000 selections developed under the last two methods are to be compared. This should give some information as to their relative value.

At times a breeder is confronted with a more definite problem. He may have a variety that is satisfactory in all but one or two characters. In this case it is obvious that the deficiency may be overcome by crossing the variety with another which has the characters he wishes to add. If a single character is to be added, it can often be approached by backcrossing. For instance, if a white color was to be transferred to O. A. C. 21, this variety might be crossed on Oderbrucker. By repeated backcrossing to O. A. C. 21, all Oderbrucker characters except whiteness and those factors linked with it would be submerged. To retain the whiteness it would be necessary to carry an occasional generation to the F_2 to be certain which lines still carried the white factor.

Real progress has been made in the testing of material. Yield tests are made in short rows repeated a sufficient number of times to give a reliable index of performance. Check rows aid in evaluating the effect of soil variations. Artificial epidemics of diseases are used at many places. These may be used before the selections are made and continued while they are being tested. In most States the selections are tested at least for yield at a number of places to smooth out environmental effects and to determine their usefulness in other

localities. In the Federal work they are often sent to many points. Selections that are only mediocre at the place where they are made often are valuable in some other locality. Strains that are superior in the nursery—a barley nursery is illustrated in figure 1—are usually grown in plots under field conditions for further proof of their value. Occasionally one is found which seems superior to those under cultivation. It is then increased and distributed to farmers.

The Germ Plasm Available to Breeders for Improvement Programs

THE barley breeding of the future must depend upon the germ plasm available to breeders. There are three distinct reservoirs of germ plasm. We have the varieties under cultivation in the United States, and these are of proven value or they would not be grown. We have the collections of unproven viable material that are being carried by the United States Department of Agriculture and State experiment stations. Lastly, in remote localities of Asia and Africa, there remains an endless number of barleys as yet unknown to American growers.

COMMERCIAL VARIETIES OF BARLEY IN NORTH AMERICA

No detailed survey of the acreage of the various varieties has been made. The survey of superior germ plasm included a request that the State agronomists estimate what percentage of the barley acreage in their respective States was planted to various varieties. These estimates are naturally not wholly dependable, but they do afford a general view of the varietal situation that would not otherwise be possible. These estimates have been translated into acreages on the basis of the July forecast. While July figures vary from the final ones obtained after the harvest, they are satisfactory in showing the general trend. Indeed, they are free from one disturbing factor—the abandonment of acreage that usually comes later. This is generally local and therefore affects some varieties more than others in any given year.

The results of the acreage estimates are reported in table 3 (p. 341). The varieties recommended by the State officials are also included.

It is apparent that most of the acreage in the United States is now being sown to varieties recently developed by plant breeders. It is obvious that such varieties are well adapted and are superior to the ones they are replacing. The plant breeder has every reason to feel gratified, and undoubtedly the time is not far distant when the entire acreage will be planted to pure-line varieties. There is, however, one rather disconcerting problem raised by the plant breeder's success. In a way we lose even when we gain. Our old varieties such as Manchuria, Coast, and Tennessee Winter contained a large number of forms. The possibilities of discovering additional strains of

unusual merit in these varieties are far from exhausted. But the acreage planted to them is shrinking rapidly. It will be difficult to maintain this particular reservoir of germ plasm in its entirety against the day when we may want it.

COLLECTIONS OF BREEDING MATERIAL

The United States Department of Agriculture maintains a collection of more than 3,000 varieties of barley. These are kept viable by growing them every few years. In a way, the maintenance of such a collection is a natural Federal function. As long as the collection is available to all State workers who desire it, the maintenance of a single large collection avoids an expensive and profitless duplication. Of course, workers in many States are maintaining extensive stocks of material in which they are interested. In Colorado and California, for instance, there are collections of interest to breeders. In Minnesota and Wisconsin there are strains thoroughly tested for their reactions to diseases. Collections in a number of other States contain valuable material. Somewhere, however, there should be preserved without loss the hundreds of barleys that have come to us through the kindness of travelers and the search of exploration parties. It may be that we will turn eventually to these little-known sorts for qualities not now recognized.

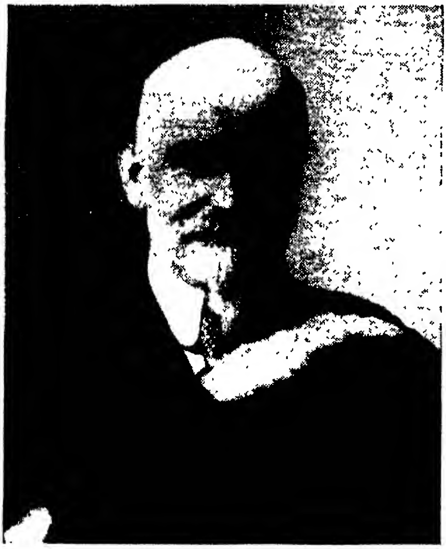


FIGURE 3.—C. A. Zavitz, Canadian plant breeder, producer of O. A. C. 21.

At present our most complete information concerns the commercial varieties. The commercial varieties of North America are quite well known. Their desirable characters have been discussed in State and Federal publications. They are available at least from commercial sources to any breeder in any amount. They are, of course, maintained in small amounts in State and Federal collections. These collections, however, include much more than the commercial varieties and are the most valuable property of the American plant breeder.

The breeder is helpless without living material of diverse character. A single strain of no commercial value may furnish a very important character. For instance, the variety, Lion, has provided the smooth-awned feature of every smooth-awned variety grown in North America today. It must be realized that full information is never available on any variety. This means that a much larger collection must be maintained than would at first seem necessary. When a new problem arises, the large number of varieties are available and a thorough search can be instituted for a quality not previously considered. More often than not a variety may prove useful in a way

not easily explained. One of the Egyptian varieties from the basins near Minia has excelled as a parent in many hybrid combinations. Yet this variety has, to date, not shown sufficient promise to be tested in field plots at any point. With a few exceptions we do not know what values may be tied up in the hundreds of barleys that lie in our collections. However, some day if a new disease should become important or a new market quality be demanded, we can turn to them as a possible starting point for a breeding program.

In addition to the variety, Lion, mentioned earlier, there are many sorts of potential value. The Ethiopian material contains varieties resistant to covered smut and to summer cold. Nakano Wase from Japan is an ideal parent for smut resistance, and breeders await only the perfection of methods of infection to make full use of it. In Pannier, an early barley from near Kashgar, Eastern Turkestan, the period in which floral organs are sensitive to frost is reduced to a point such that only scattering flowers are killed by subfreezing temperatures. Bon Farik produces large kernels and plants with few tillers; Tennessee Winter No. 52 tillers very heavily. Trebi is possessed of unusual vigor. The kernels of Smyrna enclosed in the boot continue to grow under conditions so dry that many varieties die completely. Many north-African sorts shatter but little. Peatland is resistant to lodging.

OLD-WORLD RESERVOIRS IMPERILED

In the great laboratory of Asia, Europe, and Africa, unguided barley breeding has been going on for thousands of years. Types without number have arisen over an enormous area. The better ones have survived. Many of the surviving types are old. Spikes from Egyptian ruins can often be matched with those still growing in the basins along the Nile. The Egypt of the Pyramids, however, is probably recent in the history of barley. There would be little point in building an irrigation system before there were crops to grow. In the hinterlands of Asia there were probably barley fields when man was young.

The progenies of these fields with all their surviving variations constitute the world's priceless reservoir of germ plasm. It has waited through long centuries. Unfortunately, from the breeder's standpoint, it is now being imperiled. Historically, the tribes of Asia have not been overfriendly. Trade and commerce of a sort have always existed. They have existed, however, on a scale so small that agriculture has been little affected. Modern communication is a real threat. A hundred years ago, when the grain crop of north Africa failed, the natives starved. Today, in years of shortage, the French supply their dependent populations with seed from California. Arab farmers in Mariout sometimes sell short to European buyers and import seed grains from Palestine. In a similar way changes are slowly taking place in more remote places. When new barleys replace those grown by the farmers of Ethiopia or Tibet, the world will have lost something irreplaceable. When that day comes our collections, constituting as they do but a small fraction of the world's barleys, will assume an importance now hard to visualize.

A Survey of the Achievements Made in Barley Breeding

STRANGELY enough, the first real contribution in American barley breeding was accomplished by hybridization rather than by selection, as in the case of most plants. F. H. Horsford, of Charlotte, Vt., produced a covered hooded barley more than 50 years ago. Mr. Horsford, however, was ahead of his time, and the evolution of barley improvement in the United States flowed around his accomplishment almost as if it had not existed.

THE contributions of the pioneers in breeding are not easily evaluated. They did more than breed plants. They paved the way for the generation that followed. They awakened the interest that led other men into the same fields. They effected contacts with the farming population. And with it all, they were successful breeders. They did not have adequate replications. They could not know the inheritance of many of the qualities for which they were working. They did not have available information on the role of certain diseases. Yet they did produce good barleys. This is a testimonial to the art of breeding, for it is an art as well as a science. The eye and the judgment of the breeder can never be wholly dispensed with. Judgment can be aided by perfection of technique, but many times in the handling of every extensive program the breeder must choose.

To get the story in full one must go back to the beginning. When North America was discovered there were no barleys here. Immigrants, however, always bring their seeds with them. The Spaniards were particularly fortunate in that Mexico is much like Spain in many ways and their grains were well adapted to the regions settled. Their barley arrived in New Mexico, Arizona, and California at an early date, and it was so well suited that the common Coast variety of California is still widely grown, though its origin with us dates back to the arrival of the Spaniard from Mexico. Earlier still, it traces to Spain, north Africa, and probably in some dim century to central Asia.

The barley growers along the Atlantic seaboard were not so fortunate. The English and Dutch settlers brought their grains, but the Atlantic States were not particularly good barley States, and the varieties from England and the Netherlands were not too well adapted. When western New York was reached, barley growing was advanced. Here was the first region well adapted to the growing of this crop. The six-rowed barley from Scotland was well suited to the climate, the soil, and the needs. The story was repeated in the upper Mississippi Valley, first with Scotch, then with Manchuria and Oderbrucker. When the Russians came to western Kansas they brought the Stavropol. Again, as with the Coast barley of the Spaniards, it was one naturally adapted to the new country, for the plains of western Kansas had many features in common with those of south Russia. In some

In the great laboratory of Asia, Europe, and Africa, unguided barley breeding has been going on for thousands of years. Types without number have arisen over an enormous area. The better ones have survived. Many of the surviving types are old. Spikes from Egyptian ruins can often be matched with ones still growing in the basins along the Nile. The Egypt of the Pyramids, however, is probably recent in the history of barley. In the hinterlands of Asia there were probably barley fields when man was young. The progenies of these fields with all their surviving variations constitute the world's priceless reservoir of germ plasm. It has waited through long centuries. Unfortunately, from the breeder's standpoint, it is now being imperiled. When new barleys replace those grown by the farmers of Ethiopia or Tibet, the world will have lost something irreplaceable.

way not now clear a winter barley, probably from Switzerland or the Balkans, was introduced into the mountain region of the Southeastern States where it has long been grown as Tennessee Winter and Union Winter.

When barley breeding got its second wind, then, we had these four or five varieties dominating the acreage in North America. Each consisted of a large number of strains. The component strains of each variety were similar in general character and in climatic requirements. The present position of our barley-breeding program is based largely on these varieties as a starting point.

It is difficult to say when breeding started, or in fact exactly what breeding is. Was it breeding when the farmers of western New

York decided that of the varieties introduced the small-kerneled, early, six-rowed, was the one they wanted? Probably not. A little later, however, mixed populations of Manchuria and Oderbrucker fell into the hands of the agronomists in Wisconsin, Minnesota, and Ontario. These barleys proved to be good ones and efforts were made to find others. The record is not complete and progress was slow, for little had as yet been developed in plant breeding. Efficient methods of testing were not to be developed for more than a generation. Records were usually fragmentary and knowledge of Mendel's work was yet to come.

THE WORK OF THE PIONEERS

Four men felt their way along the path of barley improvement, two in the United States and two in Canada. Willet M. Hays of Minnesota, R. A. Moore of Wisconsin (fig. 2), C. E. Saunders of Ottawa, and C. A. Zavitz of Guelph (fig. 3) were the pioneers on this side of the Atlantic. When these men turned barley breeding over to successors or assistants, the pioneer stage was over. Plot tests were reported from Wisconsin as early as 1871. Many barleys, mostly of European origin, were brought to Wisconsin to be tested in comparison with Manchuria and Oderbrucker.

After many years of experience, Moore decided that Oderbrucker was the barley best suited to his State. He set about to improve it first by elite, or mass, and later by pure-line selections. During much of the work he was aided by L. A. Stone. About 1908 Moore and Stone released Wisconsin Pedigree No. 5 and Wisconsin Pedigree No. 6. They were good varieties and are still being grown.

At Minnesota Hays had followed a somewhat different procedure. It is true there was the same preliminary period of varietal testing. Hays, however, was mostly interested in wheat. He commenced to make wheat crosses at an early date and recognized the need of more accurate methods of testing. In his breeding work he developed the centgener where 100 plants were equally spaced in a square. Barley breeding was a secondary project to Hays and, while barleys of hybrid origin were being tested in field plots as early as 1904, none was released for cultivation. Hays was responsible for a wide distribution of Minnesota 105, the original unselected Manchuria. He and H. K. Hayes are responsible for Minnesota 184, a Manchuria selection of some importance at present.

Zavitz at Guelph had much to do with the dissemination and improvement of the Manchuria-Oderbrucker barleys. He was a keen observer and his selections were good selections. His O. A. C. 21 is grown on a large acreage in Canada and is one of the important barleys in North America.

C. E. Saunders of Ottawa led the way in the production of hybrid barleys. As early as 1893 he was testing varieties of hybrid origin in field plots. His material was somewhat different from that of his three contemporaries. The Empire connections were evident in names of varieties in his test plots. Kangra Valley and Bagarmany Hills tell a story that names we are now applying may not recite. A large number of Saunders' hybrids were tested on the Dominion Experimental Farms and a few of them were grown at experiment stations in the United States. None is commercially grown this side of the border today.

The contributions of Hays, Saunders, Moore, and Zavitz are not easily evaluated. They did more than breed plants. They paved the way for the generation that followed. They awakened the interest that led other men into the same fields. They effected the contacts with the farming population that resulted in the support necessary for a broader program. And with it all, they were successful breeders. They did not have adequate replications. They could not know the inheritance of many of the qualities for which they were working. They did not have available information on the role of certain diseases, the consideration of which has played an important part in the creation of some of our new varieties. Yet they did produce good barleys. This is a testimonial to the art of breeding, for it is an art as well as a science. We can never wholly dispense with the eye and the judgment of the breeder. Judgment can be aided by perfection of technique, but, many times in the handling of every extensive program, the breeder must choose.

THE NEW GENERATION OF BREEDERS

A new generation of barley breeders eventually inherited the opportunity to advance the program of improvement. No definite date marks the transition. The earlier breeders gradually withdrew to other fields and a slow infiltration of new men took place. Breeding activities were undertaken at places where improvement previously had not been attempted. By 1910 a considerable group of new men were becoming interested and by 1920 the present situation was well indicated. The testing methods had been much improved, both in agronomic and pathological problems.

Aside from the advantage of having better tools with which to work, the new breeders necessarily followed the general lines already laid down. As with the earlier workers, improvements were made by importations, by selections in mixed varieties, and by hybridization. The machinery for securing material from abroad was greatly expanded. Several thousand barleys have been brought into the country largely through the Federal Division of Plant Exploration and Introduction.

INTRODUCED BARLEYS

While many of the introductions are invaluable as breeding stocks, few direct importations by either Federal or State agencies, aside from Manchuria and Oderbrucker, have become established in the United States. Club Mariout was brought from Egypt in 1904. In later years it was tested at a large number of stations west of the one-hundredth meridian. It was first released to the farmers of Oregon. Its largest acreage is now in California, where it is extensively grown as a crop for late seeding. It is a six-rowed, white, rough-awned variety with large kernels and a good hull. Ripened in fair weather, it assumes a golden color. Hannchen is a product of the famous plant-breeding station at Svalöf, Sweden. It has been tested widely throughout the United States. At present it is seeded on a considerable acreage in Oregon. It occurs as a mixture in fields of the upper Mississippi Valley. The fact that it seems to be increasing in this area would indicate that it could be grown there successfully

if there were any object in so doing. Hannchen is a two-rowed, white, rough-awned variety. California Mariout was introduced into California by the California Agricultural Experiment Station, having been received through E. Clemens Horst. It is a low-growing six-rowed, rough-awned barley, blue in color. It produces relatively high yields in the drier years. Once rather important, it is now grown on only a small acreage in California.

SELECTIONS FROM IMPORTED VARIETIES

Selections from importations account for a considerable proportion of the present acreage. Besides the selections from Manchuria and Oderbrucker, there are four others of some importance: Atlas, Trebi, Horn, and Tennessee Winter. Atlas is a selection of the old Coast variety. It is now grown on a larger acreage in California than any other variety. It is similar to Coast, but rather lighter in color than most strains of the original Spanish barley. It is of fine quality and has a good hull. Trebi is a selection from a mixed barley imported from the hill country south of the Black Sea. It is widely grown in the Rocky Mountain region and in the Prairie States of the northern United States and adjacent Canada. It is seeded on a larger acreage than any other variety in North America today. It is a six-rowed variety, blue in color. The crop is mostly of feed grade except in the irrigated regions, where the quality is good. Horn, a two-rowed selection from a European barley, is seeded in Montana and adjacent areas. Peatland was isolated from a barley imported from Switzerland. It is useful in heavy soils and is resistant to spot blotch, root rot, and black stem rust, and moderately resistant to scab. There are several selections of Tennessee Winter under cultivation. While several southern experiment stations have worked with this variety, the earliest selections were released in Tennessee. Two recent selections are grown on a large acreage in Texas.

SELECTIONS FROM HYBRIDS

Selections from hybrid populations are assuming more and more importance. Woven throughout the story of hybrid barleys is an obvious response to the farmers' dislike of rough awns. The awns of most barleys are stiff and heavily toothed. Such barleys are unpleasant to handle. About 1840 a variety which has a hood in place of the awn was introduced indirectly from Nepal. Its appeal to farmers was immediate and lasting. Although the yield is unsatisfactory, except in a few areas, seedsmen have always found it profitable to carry Nepal or Nepal hybrids. Most of the varieties produced by private breeders are hooded ones tracing to Nepal ancestry. As soon as Nepal was found unsatisfactory the plant breeders tried to improve it. As mentioned earlier, the first known hybrid selection in the United States was by F. H. Horsford of Charlotte, Vt., in 1879 or 1880. The Horsford variety and others originating in the same way have long been marketed under various names such as Beardless, Success, Success Beardless, etc. Among the early breeders to employ Nepal in hybrids was Robert Withecombe of Union, Oreg. He was in

an area where the Nepal types grew well under irrigation, and his work is undoubtedly the outstanding early work in the Pacific Northwest. His Union Beardless was distributed to farmers about 1910.

One of the more important projects for the production of a hooded barley started at the Tennessee Agricultural Experiment Station. C. A. Mooers (fig. 4), long connected with the chemistry department, took over the agronomic work in 1905. He immediately visualized the role that a hooded winter barley might play in the South. Farmers used to the growing of barley are willing to experience the discomfort of rough awns if thereby they can secure a higher yield. Farmers in sections where barley is little grown will seed hooded barley where they will refuse to grow a rough-awned barley. The hooded sort is much preferred for forage as well. Mooers' Tennessee No. 5 and Tennessee No. 6 have added much to the barley acreage of the South. They came from crosses of a hooded barley on Tennessee Winter. At present the acreage of winter barley in Missouri is being rapidly expanded by the use of Missouri Beardless, a hooded winter variety produced at the Missouri Agricultural Experiment Station.

FIGURE 4.—C. A. Mooers, leader in the agronomic and breeding work with winter barleys in the United States.

Shattering and low yield are the weaknesses of the hooded sorts. As the senior author pointed out in 1920, the ash or mineral content of the rachis is increased when the awns are removed, thus causing the rachis to break more easily. This is particularly important in barleys of the eastern type. Those varieties commonly grown on the Pacific coast take up less silica from the soil. They should and do produce hooded combinations which shatter less. In recent years, two hooded six-rowed hybrids involving nonshattering parents of the western type have made their appearance. These are Colsess, produced at the Colorado Agricultural Experiment Station, and Meloy, originating in Oregon probably as a natural hybrid.

One of the most interesting hybrid barleys was Arlington Awnless, developed by H. B. Derr about 1909. From the progeny of a cross of Tennessee Winter on Black Arabian, Derr isolated an awnless variety. Both parents were long-awned. The form isolated had no awns on the lateral florets and only short points on the central one. The variety shattered badly and never became commercially important. It was soon replaced in tests and as a breeding stock by a similar barley from Japan which shattered less and was more hardy. The Japanese sort may have originated in the same way at some earlier date. In any case, the Derr barley will always interest breeders from the nature of its origin.

THE DEVELOPMENT OF SMOOTH-AWNED TYPES

Perhaps the most important barley-breeding project of recent years has been that of producing smooth-awned barleys. As was the case with Nepal, the smooth-awned sorts are more pleasant to harvest. They develop better and do not shatter as badly as the hooded forms. These barleys appeal to farmers and the demand has been insistent since the first varieties of this sort were introduced.

As far as this country is concerned, the program has been based almost entirely on a single variety, Lion, a smooth-awned black barley introduced from Russia in December 1911. It was not pure when introduced and a selection made in that year was named Lion. Lion was distributed widely over the United States. It was reselected at the Michigan Agricultural Experiment Station, and their variety, Michigan Black Barbless, may differ slightly from Lion. The first crosses were made in 1911 in the cooperative work between the Bureau of Plant Industry and the University of Minnesota. A variety similar to Lion which had been found as a stray in a miscellaneous collection from Russia grown at Minnesota was first used. The 1911 barley was weak-strawed and not at all vigorous, and in 1912 Lion was substituted and it was from its progeny that the early smooth-awned barleys came.

In the Mississippi Valley the first white smooth-awned hybrid barleys were not successful, being too susceptible to helminthosporium or foot rot. One of these, however, was crossed back on Luth and several other strains of Manchuria, and the progenies were subjected to artificial infection of helminthosporium. From these crosses came Velvet and Glabron. Velvet was the first smooth-awned barley to be grown in the upper Mississippi Valley. It was released in 1926 and the acreage expanded rapidly. Velvet is a high-yielding variety of good malting quality. It has better hulls than some of the other smooth-awned barleys. It is resistant to spot blotch and root rot. Glabron was released in 1929. The straw of Glabron is better than that of Velvet. It also has some resistance to smut and stripe as well as root rot and spot blotch. It is not pure as to color, containing both white and blue strains. Its hull is not so well attached as that of Velvet. Flynn was probably the earliest of all smooth-awned varieties to be cultivated by the farmers. This barley was grown in field plots at Moro, Oreg., in 1918 and was released shortly afterwards. Hero was tested in California as early as 1914, but was not released until after Flynn was in cultivation.

The smooth-awned variety, Vaughn, is an example of a hybrid barley that was almost a success. In California it has given tremendous yields. It has a straw that is among the best of our varieties. The hull, however, is thin and frays so badly that not only is it not wanted by the maltsters, but it is also unsatisfactory where barley is rolled. The variety grows well in Arizona, New Mexico, Texas, and western Kansas. In this section, where rolling is not a common practice and where most barley is not grown for malt, it may be useful. If, by further hybridization, the hull can be improved, it should be useful in California as well.

The Michigan Agricultural Experiment Station became interested in the smooth-awned barleys at an early date. Station workers reselected Lion and introduced it as Michigan Black Barbless. They also

isolated a smooth-awned type from Hanna and later produced Spartan. Spartan is a two-rowed variety with an exceptionally good straw and quite wide adaptation. The most recent arrivals in the field of smooth-awned barleys are Wisconsin Pedigree Nos. 37 and 38. The latter appears to be the better of the two varieties and seems destined to occupy an important place in the malting area of the northern Mississippi Valley. It has a good straw and yields well.

There are a number of recent hybrid barleys which are not smooth-awned. Svansota, Minsturdi, and Alpha were developed at the Minnesota Agricultural Experiment Station. Alpha came from a cross made in the early cooperative work and was sent to the plant-breeding department of Cornell University in 1913. That department determined its value and distributed it to farmers of New York State.

THE WORK OF PRIVATE BREEDERS

The accomplishments of private breeders are not extensive. The nature of the barley crop is such that a breeder cannot retain exclusive control of the seed supplies a sufficient length of time to make it profitable. Horsford expressed this idea many years ago and even suggested a plant patent. Aside from Horsford's barley, private breeders have been responsible for a number of others. George Meloy, with the assistance of D. E. Stephens, established the variety, Meloy. A. J. Faust, of Dillon, Mont., selected the Faust variety from a field of Himalaya. Two breeders in South Carolina have made selections from the Tennessee Beardless. Each was developed from single plants. These are Douthits Beardless by J. B. Douthit, Pendleton, S. C., and Maretts Strains No. 1 and No. 2 by the Marett Farm & Seed Co., of Westminster, S. C.

It will be noted that these varieties all involve the hooded character. T. W. Wood & Sons of Richmond, Va., have promoted the use of awnless and hooded sorts. The Coker's Pedigreed Seed Co. of Hartsville, S. C., will probably be as successful with barley as they have been with other small grains. Most of the other seed firms in the United States have been concerned with the distribution phase of varieties. Many of them have given valuable cooperation in establishing new sorts, but should hardly be included in a breeding survey.

Barley breeding is, in a way, perpetual, and any survey is confronted with the difficulty of appraising unproven stocks. In many breeding nurseries throughout the country there are strains which will constitute the varieties of tomorrow. The present survey is so timed that, at some stations, established sorts are in commercial production, at others, varieties have recently been released and their possibilities are not yet fully determined. Still other varieties are soon to be offered to the growers, but at many places further testing must be done.

The Maryland Agricultural Experiment Station is expecting to release a smooth-awned winter barley in 1936. A similar variety is being produced at the Kentucky Agricultural Experiment Station, and a smooth-awned spring type has given evidence of value in Idaho.

The testing period is about completed on some strains in North Carolina. There are doubtless others in a similar stage of development that were not recorded in the survey.

The Survey of Superior Varieties of Barley

IN THE papendix (pp. 330–338) is a series of "thumbnail" sketches of the varieties of barley at present considered superior. As far as they are known, the superior qualities of each are stated. Estimates of acreage are included to show the importance of the variety. An historical paragraph gives information as to the method of production, the workers concerned, and the year the variety was released.

No such statement can be complete or fully accurate. The acreage estimates are based on the best judgment of State and Federal officials. In most cases State officials estimated the percentage of each variety in their States. These were translated into acres by using the July 1935 forecast of the Division of Crop and Livestock Estimates, Bureau of Agricultural Economics, United States Department of Agriculture.

The history of some varieties is already lost. The recording of that of others is timely. Many details can be supplied now by personal familiarity with early field notebooks. The third generation of American barley workers will not have this—and that generation is already here, but generation no. 2 does not yet realize it. The breeders directly responsible for the varieties have been recorded as completely as is possible. Unfortunately, there is no way of recording the equally valuable work of those who tested the varieties and the efforts of executives who freed the breeders from executive details and gave them the facilities for work.

The achievements of many workers have been discussed, and more are included in the sketches of barley varieties in the appendix. But there are many more instances where no concrete results in breeding can be reported. This is particularly true in the case of the present workers, many of whom are at the beginning of their careers. Often they have not been employed for a sufficient time to obtain results. In other cases the proportion of their time allotted to barley is insufficient for any adequate program. Often the activities are limited to the determination of which varieties already in existence are best suited to given conditions. This, in a way, is of the very highest service to the State. The number of commercial varieties should be limited. It is of importance in the brewing trade that varieties reach the market unmixed with others. The greater the number of varieties the more difficult this becomes. For the benefit of agriculture as a whole, these men are doing a greater service than if they evolved varieties of their own, unless of course the latter be distinctly better. Such service, however, is not of a nature that is easily recorded in this survey, except by inference in the recommended varieties. It requires more work to test a variety than to produce one.

The past and present workers in the experiment stations of the United States are listed in table 2 (p. 339). A tabulation of this sort is difficult. There is no clear-cut distinction between "early" workers and "present" workers. A man who resigned to accept a new position in 1934 cannot be listed as a "present" worker at the station which he has left. In many cases older men in charge of departments have

turned the barley work over to an assistant. They are no longer "present" workers, but at any time they may again become interested in barley. The classification as it appears here is, then, merely a matter of convenience to those who may wish to get in touch with the active workers of 1935.

A Brief Summary of the Work of Foreign Breeders

THE field of foreign activities is too broad to receive more than a brief mention in this survey. Even if we limit it to those phases of particular interest to American breeders, adequate treatment is impossible. Contacts are infrequent and the literature portrays the past rather than the present. If the information were fully available, barley breeders would doubtless be most interested in the varieties produced, the personnel, and the breeding material.

Many of the varieties produced in other countries are well known to American breeders. The more important ones have been brought in time after time and have been widely tested. As far as Canadian workers are concerned, they can hardly be considered as foreign. The barley acreage of the United States and Canada is divided by a political boundary. A variety adapted to the southern border of the Prairie Provinces of Canada is equally well suited to the northern portion of our Prairie States. Varieties are interchanged by farmers as well as by experiment stations. O. A. C. 21 is well known on our markets. Even strains that originated in noncontiguous Provinces are tested this side of the line and vice versa. Charlottetown 80, developed in Prince Edward Island, was widely tested in the United States.

Perhaps the varieties originating at the plant-breeding station at Svalof, Sweden, have had a more exhaustive trial in the United States than those of any overseas country. Svanhals, Hannchen, Primus, and Gold have been grown at practically every one of the experiment stations in the barley States. Hannchen appears in considerable quantities on our markets today.

Barley does not grow well in hot, humid climates. Under arid conditions its culture is successful even in the Tropics, but under humid conditions it grows well only in the cooler regions. The American acreage in the northern Mississippi Valley and the Eastern States is relatively far south for barley grown under humid conditions. For this reason varieties produced in England and much of Europe are not well adapted to the United States. There is a small acreage of Hanna, and at one time there was a limited acreage of Chevalier in the cool Salinas Valley of California, in the Gallatin Valley of Montana, and in parts of New England. At the present time, however, varieties from breeding stations in Europe have a limited interest to the American grower. Conditions in parts of the Union of Soviet Socialist Republics are similar to those in some localities in North America. Two Russian barleys, Odessa and Stavropol, are already grown extensively in the Plains States. The survey indicates that almost 1,000,000 acres are seeded to Odessa annually. The future

productions of Russian breeders are likely to be of great interest to American farmers.

For the more arid sections of the Plains, parts of the Great Basin, and the Pacific coast, we should look to Spain, north Africa, Chile, and Australia. Over a million acres are now seeded to varieties that trace indirectly to Spain and north Africa. The Australian varieties of barley have not as yet assumed as much importance with us as have the Australian wheats. One two-rowed variety, Pryor, is the earliest two-rowed sort in our collections. The Japanese productions are not well suited to American conditions. One of them, an awnless variety received only under the descriptive name of Nakano Wase, has a potential value as a breeding stock for smut resistance.

Mention of foreign personnel is attended with many difficulties. Their interest to American breeders is partially dependent on location. Those in regions similar to the United States in climate and soil are more likely to produce varieties of value to us than those in other sections. Complete information is never available and only a few breeders can be discussed in any case. Men like Tschermak, Regel, Nillson-Ehle, and Hans Tedin are of importance not only from their actual work, but from the direction which they gave to barley improvement in later years. The English breeders, Engledow, Hunter, and Beaven, are household names in barley literature. Vavilov (fig. 5), in the Union of Soviet Socialist Republics, is a world figure in cereals. Several of his assistants are in the front rank today. Vestergaard is outstanding in Denmark. Blaringhem, in France, despite his many and varied interests, has found time to publish many papers on barley since 1904. Old establishments such as the one at Svalöf, Sweden, and the firm of Vilmorin et Cie., in Paris, have had a profound influence. Ducellier in Algeria, Miege in Morocco, and Boeuf in Tunisia are doing work of particular interest to us. The name of Von Proskowitz is linked with the breeding work of old Austria. Many private breeders in Germany have developed barleys well known in American experiment stations. Due to the fact that their varieties are not suited to American conditions, the Japanese breeders are not so well known in North America. Their genetic work, however, is recognized as being of high standard. A few of the foreign workers are listed in the appendix.

FIGURE 5.—N. I. Vavilov, chief, Bureau of Plant Industry, Union of Soviet Socialist Republics, plant explorer and student of barley.

The breeding materials in the hands of barley breeders over the world may be of importance to us at any moment. The Russian collection is undoubtedly the most extensive in existence today. Vavilov

personally has searched almost every country of the world and has accumulated an enormous number of forms. He has sent many expeditions into the Caucasus and central Asia. Many types have been added from time to time by such explorations, as the Mongolian expendition of Pissereff. Our collections have been expanded by his generous donations. Ducellier and others have collected material from the oases of the Sahara. Some of these are very striking and may furnish us with entirely new characters to use in our breeding program.

The Need for Further Study of the Genetics of Barley

IN MANY ways barley is an attractive plant to use in inheritance studies. All cultivated barleys, so far as is known, have seven chromosomes. The number of distinct characters is large. Seed may be naked or covered; lemmas awned, hooded, or awnless; colors range from white through various anthocyanin pigments to a melaninlike black. The anthocyanin pigments may be in the lemma and palet, in the seed covering, or in the aleurone layer. Even such fundamental differences exist as in the number of fertile spikelets of a node of the rachis. There are very many minor variations.

FIGURE 6.—D. W. Robertson, leader in American barley genetics.

Unfortunately, some of the barley characters are not too readily classified. For instance, when Nepal is crossed on a barley of the Coast type, hoods and awns are secured in the usual ratio of 3 to 1. If, however, the breeder wishes a hooded segregate with the hoods fully sessile as in Nepal, the presence of other factors becomes apparent, for most of the hoods are not sessile.

The inheritance of smooth awns is equally complex. A gross classification of the progeny shows one-fourth of the awns to be smooth. Many of these are not so smooth as was the smooth-awned parent. A greater refinement suggests a two-factor relationship. In actual breeding practice, where barleys of the Coast type are used for the rough-awned parents, an assumption of still more factors may be needed.

The difficulties in barley breeding, however, are only such as the geneticist must meet everywhere, and much good work has been done.

Fortunately, the achievements tabulate well. Orderly work such as that of Robertson (fig. 6) is so clear in the tabular summary contained in the appendix (p. 341) that no discussion by a second party could add anything of value. The work of Buckley and Hor, on the other hand, was not summarized for this survey by the authors. This is not quite fair to them as they may have been able to make a more complete statement. The published reports of these authors gave no definite information as to the parents used. In both cases the ratios are summarized in one column and the linkages stated in another. In the summaries of these two authors the alignment is without significance, that is, the cross-overs are not placed opposite the ratios secured from the same hybrids. The omission of information concerning the parents is unfortunate as some other worker may wish to make use of the same material. It should be stated in connection with Buckley's cross-over percentages that in cases like red pericarp and purple lemma the classification is difficult. The intensity of anthocyanin colors depends on many factors other than genetic ones.

The nature of future studies can only be surmised. We need some method of studying the more easily influenced variants, such as time of heading and winter dormancy. Progenies grown at different places or in successive plantings at the same place give widely varying results that are difficult to analyze. We likewise need to correlate some of the activities. Mutations induced by X-rays, such as have been secured by L. J. Stadler and others, will doubtless add much to our knowledge of barley genetics. A closer contact with plant material and projects of other workers may be part of a future program. A correlation of plans for work to be done should yield many times the dividend that can accrue from any analysis delayed until independent projects are completed.

Appendix

The Desirable Characters, Acreage, and History of Superior Varieties of Barley

Ace is a two-rowed, white, rough-awned, early variety resistant to drought. It produces good yields under semiarid conditions. At present it is grown on about 117,000 acres, all in South Dakota.

The variety was distributed in 1918 from Highmore, S. Dak., the South Dakota Agricultural Experiment Station and the United States Department of Agriculture cooperating. It was produced by J. D. Morrison, who selected this and other early types from the well-known variety, White Smyrna. It is earlier and shorter than the parent variety, but otherwise similar to it.

Alpha is one of the few two-rowed varieties commercially grown in North America. It is rough-awned, white in color, has a good straw, and produces high yields in the Northeastern States. In 1935 it was grown on approximately 161,000 acres, mostly in New York State. It has proved particularly suited for growing in fields of mixed grain. The mixed-grain acreage often is not reported as barley.

The original selection was made by H. V. Harlan from a cross of Manchuria × Champion of Vermont. The selection was made at St. Paul, Minn., in the cooperative work of the Minnesota Agricultural Experiment Station and the United States Department of Agriculture. It was sent to Ithaca, N. Y., in 1913 and from there distributed to farmers through Cornell University, the United States Department of Agriculture cooperating.

Atlas is the most important barley grown in California. It is early, stiff-strawed, and produces large yields of grain of high malting quality. It is a rough-awned, six-rowed variety, less blue than Coast. It is now grown on 650,000 acres, almost wholly in California.

It was distributed from Davis, Calif., in 1924 in the cooperative work of the University of California and the United States Department of Agriculture. Atlas was one of several hundred selections made by H. V. Harlan and V. H. Florell from the Coast or common barley of California.

Arlington Awnless is apparently useful only as a breeding stock. Its one character of value lies in the fact that it produces neither awns nor hoods. There is no commercial acreage.

It was distributed in 1911 from Arlington, Va., by the United States Department of Agriculture. It was produced by H. B. Derr, who selected it from a cross of Tennessee Winter on Black Arabian. Both of these are bearded barleys.

Beldi Giant is a stiff-strawed, high-yielding, six-rowed variety with large blue kernels. The awns are quite rough and the hull is heavy but good. The present acreage is about 27,000 acres, all in the State of Washington. The origin is not clear. It was secured from the California Agricultural Experiment Station by the United States Department of Agriculture about 1913 under the name of Beldi. It differed so materially from the Beldi of the Department of Agriculture that H. V. Harlan made a selection of it, renamed it Beldi Giant, and sent it to a considerable number of western stations. It was later distributed to farmers by the Washington Agricultural Experiment Station. Beldi Giant is probably an introduction from north Africa. The word Beldi is most likely a corruption of the Arabic term for "village." In other words, Beldi probably means "common" barley and varies from place to place in north Africa.

California 4000 is limited in its distribution to California, where the present acreage is about 12,000 acres. It is a six-rowed, rough-awned, blue barley that produces high yields of grain suitable for both feed and malting.

The variety is a product of the California Agricultural Experiment Station. It was released to farmers in 1916. It is a selection made by B. A. Madson from Coast, the common barley of California.

California Mariout is a six-rowed, rough-awned, low-growing, blue-kerneled variety. It is very early and produces good yields with relatively little moisture. The grain is of feed quality and the variety is adapted only to California and the Southwest. Although formerly grown on a considerable acreage, there is little in cultivation at this date.

G. W. Shaw and G. W. Hendry distributed California Mariout in 1912. It was an introduction from Egypt which they secured through E. Clemens Horst, of San Francisco. In Egypt the variety is grown by Arab farmers along the Mediterranean, where it matures without irrigation with a rainfall of about 8 inches.

California Tennessee Winter is adapted to the heavier lands of California, where it produces high yields of grain suited for both feed and malting. It is not a true Winter barley and is not similar to the Tennessee Winter of the Southeastern States. It is of the Coast type with harsh awns and blue kernels. The California Tennessee Winter has an acreage of 118,000 acres, all of which is in California.

It was selected by B. A. Madson and distributed by him in 1916. Its origin is not certain, but it is thought by the California authorities to be a selection of one of the Coast types.

Club Mariout is particularly valuable for late seeding in California, where the shortened period from planting time until maturity is well utilized by this variety. It also yields well under conditions of light rainfall, as in eastern Oregon and eastern Colorado. It is a six-rowed, rough-awned variety, with a dense head of white kernels. In 1935 the acreage of Club Mariout was estimated to be 233,000 acres, most of which is in California.

The variety was introduced by the United States Department of Agriculture from the irrigated sections of lower Egypt in 1903. The first commercial acreage was in Oregon. In 1919 G. W. Hendry brought some of the barley into California in carload lots. It has been a staple barley there ever since.

Coast has long been popular with the English brewers. It has been the major feed grain of the Western States since their settlement, and in certain sections such as the interior valley of California the quality is high. It is a mixture consisting of a large number of strains of six-rowed, rough-awned barley. These strains vary in the amount of blue pigment they contain. At present it is grown on about 328,000 acres, the largest areas being in California and Colorado.

This variety was introduced into California about 1770 by the early Spanish missionaries from Mexico. Earlier it doubtless came to Mexico from Spain and to Spain from north Africa.

Colsess is a hooded, stiff-strawed variety which has given high yields in Colorado. It shatters less than many of the hooded sorts. It is seeded on about 18,000 acres, all in Colorado.

It was distributed in 1911 by the Colorado Agricultural Experiment Station. It was developed by D. W. Freer and the staff of the Colorado station, from a hybrid of Coast × Beardless.

Comfort and Short Comfort are smooth-awned, six-rowed varieties which produce good yields. On the whole they are not so smooth as Glabron and Wisconsin Pedigree 38. Comfort was produced at the Minnesota Agricultural Experiment Station in the cooperative work of the United States Department of Agriculture in the smooth-awned project of Hayes, Harlan, Stakman, etc. It came from a cross of a smooth-awned segregate, Manchuria × Lion crossed on Luth. Luth is a plant selection of Manchuria made by Harlan in southeastern Minnesota. Two separate lots were sent to the Nebraska Agricultural Experiment Station. One of these was found by Kisselbach to be shorter than the other and he distributed it to farmers as Short Comfort. At present Short Comfort is grown on about 121,000 acres in Nebraska, while Comfort is grown on 53,000 acres in Nebraska and Pennsylvania.

Esaw is a productive winter variety resistant to covered smut. It is an early, six-rowed, rough-awned, white-kerneled variety. The commercial acreage is unimportant.

Esaw was distributed from the Arlington Experiment Farm in 1930 by the United States Department of Agriculture. It was selected from a Nakano Wase hybrid by J. W. Taylor.

Ezond is the result of an effort to develop a smooth-awned Trebi barley. It is believed that this variety possesses the vigor and yielding capacity of the Trebi parent, but this is not yet fully demonstrated. There is no commercial acreage.

Ezond came from a cross of Trebi on Louden made by G. A. Wiebe. Louden is a smooth-awned segregate of Bay Brewing × Lion. The F_1 and plants of later generations were backcrossed on Trebi. A segregate was increased and tested several years ago at Aberdeen, Idaho, where all the work has been done in cooperation between the United States Department of Agriculture and the Idaho Agricultural Experiment Station. The first segregate produced high yields and was tested at a limited number of experiment stations. The smooth-awned character was not fixed. Some plants were partially smooth, some slightly rough, and some quite smooth. Harland Stevens at Aberdeen, Idaho, made a large number of selections from the variety. A few of these proved to be entirely smooth and have remained so in larger tests now being conducted. The best of these again carries the name Ezond.

Faust is a hooded, naked, six-rowed barley of the Nepal type. It has produced high yields for this type of barley in western Montana. The variety is grown on 6,000 acres, all in Montana.

A. J. Faust, of Dillon, Mont., found a hooded plant in a field of Himalaya. It obviously was a field hybrid, probably of Nepal × Himalaya. He increased the seed of this plant and the variety known as Faust was later grown by him and tested by the Montana Agricultural Experiment Station.

Featherston is a six-rowed, rough-awned barley of the Manchuria type which produces high yields in the Northeastern States. Although more widely grown at one time, it is now limited to about 3,500 acres, all in New York State.

Featherston came from a selection made by H. V. Harlan in a field of Manchuria barley near Red Wing, Minn. It was first grown at St. Paul, Minn., in cooperative work with the United States Department of Agriculture and the Minnesota station. It was sent to Ithaca, N. Y., in 1913, where it was tested in the cooperative work of the Department and Cornell University and distributed to farmers from that place.

Flynn is a six-rowed, smooth-awned, white-kerneled barley with a good straw and of moderate height. It has produced good yields in eastern Oregon and in western Kansas. The commercial acreage is insignificant.

Flynn came from a cross of Club Mariout × Lion made at St. Paul, Minn., by H. V. Harlan in the cooperative work between the Minnesota station and the United States Department of Agriculture. A number of selections from this cross, including Flynn, were sent to several western stations. At Moro, Oreg., Flynn was chosen by D. E. Stephens in the cooperative work between the Department and the Oregon station as the best of these selections and was distributed to farmers.

Glabron is one of the more important smooth-awned barleys. It has an unusually good straw, yields well, is resistant to smut, spot blotch, and root rot, and moderately resistant to stripe. It is adapted to the upper Mississippi Valley, where it is now grown on 813,000 acres.

Glabron was distributed from the Minnesota Agricultural Experiment Station in 1929. It was produced in the cooperative work between the Minnesota station and the United States Department of Agriculture. Its history is slightly involved. In the early development of the smooth-awned barleys, Lion was crossed on Manchuria. A smooth-awned segregate from this cross was used in 1917 to cross again on Manchuria. From the second cross, Glabron was isolated. In the production of the variety H. K. Hayes, H. V. Harlan, F. Griffee, E. C. Stakman, and J. J. Christensen all had a part. The plant-breeding and plant-pathology sections of the university joined forces to isolate selections valuable for their agronomic characters and resistant to some of the serious diseases. Glabron is a good example of profitable cooperation between those engaged in agronomic and those engaged in pathological research.

Hannchen has given better yields and has exhibited a much wider range than other barleys imported from Svalof, Sweden, and similarly has the widest range of any two-rowed barley grown in North America today. It has a good straw and produces grain of high quality. It is now grown on more than 60,000 acres, more than three-fourths of which are in Oregon.

Hannchen came from a plant selection made from Hanna at the plant-breeding station at Svalof. It was introduced into the United States by the Department of Agriculture in 1904. It was distributed to a large number of stations and was in the hands of farmers about 1908. The Oregon stations have found it well suited to western Oregon and the irrigated districts of the Klamath section. It is surviving as a mixture in other varieties in the northern Mississippi Valley, where it seems to be increasing in the fields.

Hero is a six-rowed variety with smooth awns and a good straw. It yields well in a limited section of California and under irrigation in southern Arizona. It is grown on about 60,000 acres, practically all of which are in California.

The history of Hero is interesting because of the number of agencies involved in its development. A cross between Lion × Club Mariout was made in the Federal greenhouse, Rosslyn, Va., in 1912 by H. V. Harlan. Two generations of progeny were grown at St. Paul, Minn., in cooperation between the Federal Department of Agriculture and the Minnesota Agricultural Experiment Station. Several plant selections were made and sent to experiment stations in the West, including Chico, Calif., in 1915. The variety was grown at Chico until 1921. In 1922 the variety was named Hero, and in the same year the work was transferred to Davis. Later, W. W. Mackie, of the California Agricultural Experiment Station, made a plant selection which he distributed in 1924 to California growers as Hero. It is obvious that this variety would not be in the hands of farmers today if any of the steps in the Federal and State cooperation had been lacking. It is equally obvious that scientific credit cannot be apportioned or decided. The work was done, however, through facilities afforded by the University of California and was made possible by the cooperation of B. A. Madson. Madson's part in the production of the more important variety, Atlas, at the same station is even more valuable. Through his assumption of the administrative details, the workers who developed that variety were able to devote their time to the details of the breeding program.

Himalaya is a blue, naked, rough-awned, six-rowed barley. It is the highest yielding naked sort grown in North America. It is grown scatteringly throughout the West, but most of its 5,000 acres are in Montana.

It is a common barley of central Asia and extends to the higher altitudes in northern India. It has been imported many times, tested at most of the experiment stations in the United States, and released at various places.

Horn is a rough-awned, white, two-rowed barley which has produced high yields on the dry lands of Wyoming and Montana. It is now grown on 110,000 acres, and its distribution is limited mostly to Montana, Wyoming, and South Dakota. The acreage was considerably in excess of this figure, before the recent drought period, in the area of its distribution.

The parent material was secured at the Paris Exposition in 1900 from the Austrian exhibit. In 1909 H. V. Harlan made the selection of the present variety at St. Paul, Minn., in the cooperative work between the University of Minnesota and the United States Department of Agriculture. The variety was tested at a number of western stations, but was probably first released in Wyoming. In

recent years the Montana Agricultural Experiment Station has done much to extend the acreage of Horn in Montana.

Horsford is a hooded, covered, six-rowed barley grown here and there throughout the Eastern and Midwestern States. The variety shatters badly and does not produce high yields. It is estimated that 34,000 acres are planted annually to this variety.

The term Horsford includes a number of similar barleys of separate origin. The first of these was produced by Mr. Horsford, of Charlotte, Vt., in 1879 or 1880. It was a cross of Nepal on one of the common six-rowed, bearded barleys of the Eastern States. Similar crosses were made later, and field hybrids of Nepal are not uncommon. Seedsmen have carried this sort of barley under various names, Success and Success Beardless being two of the more common.

Kentucky 1 and *Kentucky 2* are both winter-hardy and adapted to Kentucky conditions. Kentucky 1 produces the higher yield and is grown on between 2,000 and 3,000 acres, most of which are in Kentucky and Missouri.

These varieties were selected from the old winter barley long grown in Kentucky and commonly known as Tennessee and Union Winter. The plant selections were made by E. J. Kinney, of the Kentucky Agricultural Experiment Station, who released them to farmers in 1930.

Kentucky 11 is a smooth-awned, six-rowed, cold-resistant winter barley. It has no farm distribution as yet.

This variety was produced by E. J. Kinney, of the Kentucky station. It came from a cross of a smooth-awned spring variety on the local winter.

Lion has been widely used as a parent in hybrids. It is smooth-awned, black, six-rowed, and of fair yielding capacity. Its main contribution is an unusually smooth awn that is highly stable for smoothness. There is no commercial acreage.

In 1911 the United States Department of Agriculture received a black, six-rowed barley from Taganrog, Russia. A small plot was grown at St. Paul, Minn., in 1912 in the cooperative experiments of the United States Department of Agriculture and the Minnesota station. Both smooth and rough types were present. H. V. Harlan made a number of selections, one of which (Lion) was used in crosses and distributed to many experiment stations.

Michigan Black Barbless: In 1913 Lion was sent to the Michigan Agricultural Experiment Station. F. A. Spragg reselected the variety and in 1918 released his selection as Michigan Black Barbless. It is grown on about 2,000 acres in Michigan.

Since Lion was already a pure line, any difference at Michigan must have been due to accidental impurity of the seed. It is possible that the Lion sent included other strains of the original Taganrog barley.

Manchuria is a vigorous, six-rowed, rough-awned, early barley tolerant to moderately high temperatures and humidity. The estimated acreage of this variety in 1935 was 1,229,000.

The first importation of Manchuria seems to have been made about 1861, when Herman Grunow, of Miffen, Wis., secured it from Germany. It was later grown as Minnesota 6 and under such names as Manshury and Mansury. In 1881 the Ontario Agricultural College at Guelph, Canada, imported a barley which they distributed as Mandscheuri. It was similar to the earlier introduction. Both barleys contained a large number of strains, some with blue aleurone layer, some with white. Many valuable selections have been made from these stocks.

Minnesota 184 is a selection of the original Manchuria. It is superior in yield and malting quality, and is resistant to spot blotch and root rot, and moderately so to loose smut. It was grown on 668,000 acres in Minnesota in 1935.

It was selected from Minnesota 105, the Ontario Mandscheuri. The selection was made and tested by W. M. Hays, C. P. Bull, and H. K. Hayes. It was distributed in 1918.

Meloy is a hooded, six-rowed, blue variety which shatters less than do most hooded hybrids. It is grown on about 8,000 acres in eastern Oregon.

The variety, a field hybrid, was found by George Meloy near Moro, Oreg. One parent was probably a barley of the Coast type. D. E. Stephens secured the variety from Meloy and, after testing it in the cooperative tests of the Oregon Agricultural Experiment Station and the United States Department of Agriculture at Moro, distributed it to farmers in Oregon.

Michigan Winter is one of the more winter-hardy barleys. It is six-rowed and rough-awned. It is grown on about 2,000 acres in Michigan.

The variety came from from a plant selection Derr Winter made by F. A. Spragg. The Derr Winter was probably of the Tennessee Winter type. The Michigan station distributed this variety in 1914.

Missouri Early Beardless is an early, hooded, six-rowed winter barley particularly well adapted to southern Missouri. It was grown on about 1,000 acres in 1935. In the fall of 1935 the seeding was increased to about 12,000 acres.

The variety was produced by C. A. Helm at the Missouri Agricultural Experiment Station by mass selection in a commercial variety without name. It was first distributed by the Missouri station in 1933.

Nakano Wase is valuable as a breeding stock. It is an early, awnless, six-rowed winter variety with good straw and is resistant to smut. There is no commercial acreage.

The present selection of Nakano Wase was made by J. W. Taylor and released in 1924 from the Arlington (Va.) Experiment Farm. The parent variety was introduced by the United States Department of Agriculture from Japan in 1911 under the purely descriptive name of Nakano Wase (meaning medium early).

Nobarb is a smooth-awned, six-rowed winter barley. It is one of the varieties to be released in 1936. It was produced by W. B. Kemp, of the Maryland Agricultural Experiment Station, from a hybrid Tennessee Winter × Smooth-Awn.

North Carolina Hooded is a hooded barley well suited to North Carolina conditions. At present this variety is grown on about 3,500 acres.

With the expansion of barley growing in North Carolina, a number of types have evolved; one of the best of these is the North Carolina Hooded. This designation may include a number of barleys, or at least a barley that is not wholly uniform.

The *Oderbrucker* barleys as known at present are six-rowed, rough-awned varieties with white kernels. They are particularly prized by maltsters in the upper Mississippi Valley. They yield well and are stiff-strawed and moderately tolerant to summer heat and humidity. Oderbrucker selections were grown on 1,024,000 acres in 1935.

Oderbrucker was originally a variety identical with or similar to the Manchuria. As with the latter variety, it consisted of a large number of strains, both blue and white. A report in the old Government records of 1865 states: "This variety is grown very extensively on the low, formerly swampy lands of the Valley of the Oder, but which were drained during the reign of Frederick the Great." An importation by the Federal Government apparently never reached the farmers. In 1889, however, the Ontario Agricultural College at Guelph received this barley from Germany and later sent it to the Wisconsin Agricultural Experiment Station. It was widely distributed by the Wisconsin Station and most of the improvement was made at that place. In 1908 R. A. Moore and A. L. Stone of Madison released Wisconsin Pedigree 5 and Wisconsin Pedigree 6. Both of these were selections of Oderbrucker. They constitute the entire Oderbrucker acreage today.

Odessa is similar to Manchuria in many ways. It is rough-awned and six-rowed, with kernels about the same size as Manchuria. It is even more tolerant to summer heat and probably to drought. It is particularly adapted to eastern South Dakota, where it yields well. It is estimated that it was grown on 955,000 acres in 1935, almost all of which were in South Dakota.

Odessa was grown in the test plats at Ottawa, Canada, in 1890. It was obviously an importation from south Russia. It was obtained from Ottawa in 1902 by the United States Department of Agriculture and later sent to a number of experiment stations. The South Dakota Station tested it thoroughly and released it to farmers in 1914.

The *Oklahoma Winter* barley is pecularily adapted to Oklahoma, Missouri, southwestern Kansas, and the Texas Panhandle. It is six-rowed, rough-awned, and moderately winter-hardy. It was grown on about 120,000 acres in 1935. Oklahoma Winter is the result of natural evolution. Tennessee Winter, Michigan Winter, and even some of the northern spring types were brought into Oklahoma for fall seeding. Gradually a type emerged which differs from any of these in the nature of its cold resistance. It is more tolerant to the dry cold of that section than is Tennessee Winter. On the other hand it is not as winter-hardy as Tennessee Winter when grown in Virginia. Oklahoma Winter is probably the result of natural selection in a mixed variety.

O. A. C. 7 is a six-rowed, rough-awned, white-kerneled variety which gives high yields in western Oregon, where it can be seeded either in the fall or in early spring. It is grown on slightly more than 9,000 acres, all in western Oregon.

The variety originated as a plant selection made by G. R. Hyslop from Webb's New Hardy White Winter. It was distributed from the Oregon Agricultural Experiment Station in 1909.

O. A. C. 1 and *6* are six-rowed, rough-awned, white barleys of the Tennessee Winter type. No. 1 is apparently somewhat more winter-hardy than no. 6. The commercial acreage is small.

E. N. Bressman, when with the Oregon Station, selected some of the surviving plants of Tennessee Winter following an unusually cold winter at Corvallis. The progeny of two of these were distributed in 1925 as O. A. C. 1 and O. A. C. 6.

Orel is a two-rowed, rough-awned, white-kerneled winter barley. It yields well and has a good straw and very long heads, but is only moderately winter-hardy. It can be seeded in the spring if seeded early. There is a nominal acreage in Virginia.

Orel was secured by the United States Department of Agriculture from Russia in 1904 through L. L. Bolley of North Dakota. A selection of Orel was released in 1925 from the Arlington Experiment Farm, Rosslyn, Va., by J. W. Taylor. The original importation, grown at Aberdeen, Idaho, has assumed a habit quite different from that of the variety as grown at Arlington. Probably the variety was not pure for all characters and natural selection has resulted in a different type.

Peatland is a six-rowed, rough-awned, stiff-strawed sort, resistant to spot blotch, root rot, and black stem rust, and moderately resistant to scab. It was grown on about 2,300 acres in Minnesota in 1935.

It was produced by H. K. Hayes and H. V. Harlan in the cooperative work between the Minnesota Agricultural Experiment Station and the United States Department of Agriculture. It is a selection of a barley from Canton Lucerne, Switzerland, which was presented to the United States Department of Agriculture by Albert Volhart of Zurich. The Swiss barley was an unimproved variety containing many types. Peatland was released to farmers in 1926.

Sacramento is a dense, stiff-strawed, six-rowed, rough-awned, blue variety resistant to smut and mildew. It is not commercially important, probably due to its lateness.

It was produced by W. W. Mackie of the California Agricultural Experiment Station from a hybrid of Cape × Coast.

Spartan is a two-rowed, smooth-awned, early variety with an unusually stiff straw. It is grown on about 128,000 acres, mostly in Michigan and Nebraska.

It was selected from a hybrid, Michigan two-row × Black Barbless, which was made by E. E. Down and H. M. Brown. It was released to farmers in 1918.

Stavropol is a rough-awned, six-rowed, blue-kerneled barley closely related to Coast. It is grown on about 200,000 acres, mostly in Kansas, where it yields well and is resistant to drought.

This variety was doubtless brought into western Kansas by the Russian immigrants. A similar barley, however, was obtained by M. A. Carleton of the United States Department of Agriculture from near Stavropol, Russia, in August 1900.

Tennessee Beardless 5 and 6 are hooded winter sorts adapted to the southern winter barley section. It is estimated that they were grown on 35,000 acres in 1935. Most of the acreage is in North Carolina, Tennessee, and Missouri.

They were produced by C. A. Mooers of the Tennessee Agricultural Experiment Station, who crossed Tennessee Winter on a hooded spring barley, probably of the Horsford type. Professor Mooers released them to farmers in 1915

Tennessee Winter is the most vigorous and most widely adapted of our winter barleys. It is a rough-awned, six-rowed variety, the kernels of which are similar to Manchuria in both size and character. The variety is not pure and local changes have taken place in widely separated sections. It is annually grown on about 210,000 acres in our Southern States, from Maryland to Oklahoma.

Its origin is not known, but at some time it probably came into the South from Switzerland or the Balkans. The variety Union Winter and the Kentucky local barley are likely of the same stock. The lot released from the Tennessee station as Tennessee Winter has been most widely grown.

Tennessee Winter 52. This selection of Tennessee Winter is similar to the parent variety but has unusual stooling capacity and yields well. It is susceptible to smut.

H. V. Harlan made a considerable number of selections of winter barley in the fields of Tennessee and Kentucky. Curiosity led to the inclusion of no. 52 in more elaborate tests because, although it was highly susceptible to smut at Rosslyn, Va., it produced high yields. It was distributed to a number of places, and Mooers found its stooling capacity and yielding qualities to outweigh its moderate susceptibility to smut at Knoxville.

Tennessee Winter Texas 12576. This selection of Tennessee Winter has broader leaves and a shorter but larger head, and the grain is earlier in maturity and less dormant than the typical Tennessee Winter. It produces high yields in Texas, where it is grown on 121,000 acres.

The variety was produced by mass selection from Tennessee Winter by A. H. Leidigh and C. H. McDowell at the Denton (Tex.) station. It was released in 1918.

Tennessee Winter Texas 643–33 is a selection of Tennessee Winter. It is winter-hardy and yields well. It is now grown on about 10,000 acres.

The selection was made and tested by A. H. Leidigh and P. B. Dunkle. It was released in 1924.

Trebi is a barley of exceptional vigor. It yields well even in sections where it appears to be too late to escape heat damage and to be too susceptible to disease injury for the best results. It is grown from Minnesota to Nevada. It is six-rowed and rough-awned and has large blue kernels. As grown in the upper Mississippi Valley, it is not desired by the maltsters, but produces large amounts of feed grain. Under irrigation in the Rocky Mountain region, the quality is better and it has produced large yields. One farm yield of 131 bushels per acre is reported under irrigation. Trebi was grown on 2,224,000 acres in 1935, the largest acreage of any single variety.

A barley from the south side of the Black Sea was secured by the United States Department of Agriculture in 1905. It was grown in cooperation with the Minnesota Agricultural Experiment Station in 1909. H. V. Harlan isolated a number of distinct types in that year. In 1913 they were sent to Aberdeen, Idaho, where they were tested in cooperation with the University of Idaho. Trebi was released from Aberdeen in 1918.

Union Beardless is a hooded, naked, six-rowed variety. It is leafy, erect, and prized for hay. It is adapted to the irrigated valleys of eastern Oregon. It was grown on 12,000 acres in 1935, all in Oregon.

Union Beardless was produced by Robert Withecombe by hybridization at the Union branch station. It was released in 1910.

Vaughn is the most vigorous six-rowed, smooth-awned barley grown on the Pacific coast. It produces very high yields, is stiff strawed, and early. The hull, however, frays, and consequently this variety is not wanted by maltsters or barley rollers. It was grown on about 7,000 acres in California and Arizona in 1935.

Vaughn came from a hybrid of Lion × Club Mariout. The hybrid was made by H. V. Harlan in the greenhouse at Rosslyn, Va., in the winter of 1912–13. The first and second generations were grown at the University of Minnesota in the cooperative work with the United States Department of Agriculture. Vaughn was selected from the hybrid population and sent to Moro, Oreg., in 1916. It was included in the nursery at Davis, Calif., in 1922. Its first-yield test at that place was made under the supervision of V. H. Florell in 1924 in the cooperative work of the California Agricultural Experiment Station and the United States Department of Agriculture. The variety was released in 1926.

Velvet is a smooth-awned, six-rowed hybrid with white kernels. The hull is better than that of some of the smooth-awned sorts. The variety produces high yields of grain of good malting quality. It is resistant to spot blotch and root rot. It was grown on 1,726,000 acres in 1935, the second largest acreage of any single variety.

Velvet is a product of the cooperative work of the Minnesota Agricultural Experiment Station and the United States Department of Agriculture. Manchuria was crossed on Lion in the Washington (D. C.) greenhouse by H. V. Harlan in the winter of 1912–13. Smooth-awned segregates were isolated from this cross in the cooperative work at the Minnesota Station. None of these seemed superior, and at the request of H. K. Hayes one of the segregates was crossed on Luth (a Manchuria selection) by Harlan in 1917. As a matter of convenience this cross was made at Aberdeen, Idaho, and to save time the F_1 was grown in the greenhouse at Rosslyn, Va., in 1917. This made it possible to grow the F_2 in Minnesota in 1918. Subsequent generations were grown at St. Paul, Minn., in a special disease nursery by the plant genetic and plant pathology sections of the university. Velvet was selected under these conditions. H. K. Hayes, F. Griffee, E. C. Stakman, and J. J. Christensen played an important part in these tests. The variety was released in 1926.

White Smyrna is two-rowed, semirough-awned and white. It is a low-growing sort, the spike of which is often only partially exserted from the boot. It is large-kerneled, drought-resistant, and early. It was grown on 170,000 acres in 1935, mostly in South Dakota and Colorado.

Smyrna was first received by the United States Department of Agriculture in 1901 through George C. Roeding of Fresno, Calif., who obtained it from B. J.

Agadjanian of Smyrna. It was sent to many experiment stations and the date it was released to farmers is not known.

Winter Club is a dense, six-rowed, white barley of moderate winter hardiness. It will grow from spring seeding if seeded early. It is stiff-strawed and yields well in the Great Basin and the Pacific Northwest. It was grown on about 19,000 acres in 1935, mostly in Washington, Idaho, and Utah.

The variety is old in North America and its history is not known. The first sample received by the Department came from George A. Smith of Lewiston, Idaho, in 1903. A record of 1907 from Nephi, Utah, states that the barley had been grown there for 35 years and was probably introduced from California. It was extensively grown in Utah before it was displaced by Trebi.

Wisconsin Pedigree 37 and *38* are smooth-awned, white, six-rowed varieties. They have good straw, are resistant to stripe, and produce high yields of grain of good malting quality. They are popular and were grown on 873,000 acres in 1935. Wisconsin Pedigree 38 seems to be the better of the two and most of the acreage is of that variety.

Both varieties were produced by B. D. Leith of the Wisconsin Agricultural Experiment Station. They came from a cross of Wisconsin 5 and Lion. Wisconsin 5 is an Oderbrucker. The varieties were released in 1929–30.

Wisconsin Winter is a rough-awned, six-rowed variety adapted to fall seeding in the southeastern winter barley area. It is early and yields well. Its present acreage is nominal.

The origin of the parent barley is not known, but it probably came from the Balkans. It was first secured by the United States Department of Agriculture in 1905 from Texas. The Texas correspondent stated that he secured it from La Crosse, Wis., in 1898. The present variety came from a selection made by J. W. Taylor at the Arlington Experiment Farm at Rosslyn, Va. This selection was released in 1922.

TABLE 1.—*Present objectives of barley breeders at United States experiment station.*

[Yield is omitted as all breeders are working to secure higher yielding varieties]

Location of station	Smooth awns	Hoods	Naked	Quality	Stiff straw	Winter hardiness	Earliness	Cold resistance	Tillering	Nonshattering	Forage	Resistance to— Covered smut	Loose smut	Stripe (*Helminthosporium gramineum*)	Foot rot spot blotch (*H. sativum*)	Scab (*Gibberella saubinetti*)	Fusarium foot rot	Mildew	Rust (black stem)	Blight
California, Davis	+	+	+				+					+		+				+		
Colorado, Fort Collins	+			+																
Georgia, Experiment		+				+					+									
Idaho, Aberdeen	+	+		+	+			+	+	+		+								
Idaho, Moscow	+			+	+															
Illinois, Urbana	+			+					+											
Indiana, Lafayette	+					+														
Iowa, Ames				+	+															
Kentucky, Lexington	+					+														
Maryland, College Park	+					+														
Michigan, E. Lansing	+			+	+	+							+							
Minnesota, St. Paul				+	+							+	+	+	+	+	+		+	+
Missouri, Columbia		+				+	+				+									
Montana, Bozeman	+		+	+	+		+			+										
Montana, Moccasin				+	+															
New Jersey, New Brunswick	+			+	+				+	+	+							+		
New Mexico, State College	+																			
New York, Ithaca	+											+	+							
North Carolina, Raleigh		+										+	+							
North Dakota, Fargo				+																
Ohio, Columbus and Wooster	+			+																
Oklahoma, Stillwater						+	+													
Oklahoma, Woodward						+														
Oregon, Eastern	+	+		+	+	+				+		+								
Oregon, Western	+			+	+	+	+								+			+		
South Dakota, Brookings				+	+															
Tennessee, Knoxville									+											
Texas, Denton						+						+	+							
Utah, Logan	+				+							+		+						
Virginia, Rosslyn	+					+						+								
Washington, Pullman		+			+	+						+								
Wisconsin, Madison	+			+	+							+	+	+		+				

TABLE 2.—*Past and present workers in the United States who have devoted or are devoting part or all of their time to barley improvement*

[An asterisk (*) designates workers all or part of whose salaries are paid from Federal funds]

Location of workers	Early workers	Present workers
Washington, D. C.	H. B. Derr,* S. A. Anthony,* Albert Mann.*	H. V. Harlan,* G. A. Wiebe,* M. N. Pope,* Mary L. Martini,* and Lucille Reinbach.*
Arizona, Tucson		A. T. Bartel.*
Arkansas, Fayetteville		C. K. McClelland.
California, Davis	G. W. Shaw, G. W Hendry, W. W. Mackie, V. H. Florell,* and G. A. Wiebe.*	F. N. Briggs and C. A. Suneson.*
Colorado, Akron		J. J. Curtis.*
Colorado, Fort Collins	D. W. Frear and G. W. Deming	D. W. Robertson, Dwight W. Koonce, and Dean C. Anderson.
Georgia, Experiment		R. P. Bledsoe and S. J. Hadden.*
Idaho, Aberdeen	L. C. Aicher* and G. A. Wiebe.*	Harland Stevens* and John L. Toevs.
Idaho, Moscow	V. H. Florell*	C. A. Michels and W. M. Bever.*
Illinois, Urbana		O. T. Bonnett.
Indiana, Purdue		R. R. Mulvey and G. H. Cutler.
Iowa, Ames		L. C. Burnett* and J. B. Wentz
Kansas, Hays		A. F. Swanson.*
Kansas, Manhattan		J. H. Parker.*
Kentucky, Lexington		E. J. Kinney.
Maryland, College Park		R. G. Rothgeb and W. B. Kemp.
Michigan, East Lansing	F. A. Spragg	J. W. Thayer, Jr., and E. E. Down.
Minnesota, St. Paul	Willet M. Hays, H. K. Hayes, E. C. Stakman, F. J. Stevenson, LeRoy Powers, and C. P. Bull.	J. J. Christensen and F. R. Immer.
Missouri, Columbia	C. A. Helm	E. M. Brown.
Montana:		
Bozeman	LeRoy Powers, J. E. Norton, and Austin Goth.	L. P. Reitz.
Havre		M. A. Bell.
Moccasin	E. L. Adams,* N. C. Donaldson,* and R. W. May.*	J. L. Sutherland.*
New Jersey, New Brunswick		R. E. Blaser, G. W. Burton, M. E. Paddick, and H. B. Sprague.
New Mexico, State College	W. T. Conway	J. C. Overpeck and Glen Staten.
New York, Ithaca		F. P. Bussell, W. T. Craig,* and H. H. Love.
North Carolina, State College Station.		G. K. Middleton.
North Dakota:		
Fargo	T. E. Stoa and L. R. Waldron.	R. W. Smith.*
Dickinson		J. C. Brinsmade, Jr.*
Mandan		L. E. Thatcher and J. B. Park.
Ohio, Columbus and Wooster		
Oklahoma:		
Stillwater		C. B. Cross.
Woodward	Edmund Stephens*	V. C. Hubbard.*
Oregon:		
Burns		Obil Shattuck.
Corvallis	G. R. Hyslop, C. C. Ruth, and E. N. Bressman.	D. D. Hill.
Moro		D. E. Stephens.*
Pendleton		J. F. Martin.*
Union	Robert Withycombe	D. E. Richards.
South Dakota, Brookings	A. N. Hume, Manley Champlin, and E. S. McFadden.*	K. H. Klages.
Tennessee, Knoxville	C. A. Mooers	H. P. Ogden and Newman Hancock.
Texas:		
College Station	A. H. Leidigh	P. C. Mangelsdorf.
Denton	C. H. McDowell	I. M. Atkins* and P. B. Dunkle.
Utah, Logan	George Stewart	R. W. Woodward* and D. C. Tingey.
Virginia, Arlington Experimental Farm.		V. F. Tapke* and J. W. Taylor.*
Washington, Pullman		E. F. Gaines, O. E. Barbee, E. G. Schaefer, and O. A. Vogel.*
West Virginia, Morgantown		L. S. Bennett, and R. J. Garber.
Wisconsin, Madison	R. A. Moore and A. L. Stone	B. D. Leith, H. L. Shands, J. G. Dickson,* R. G. Shands,* and A. D. Dickson.*
Wyoming, Laramie	B. C. Buffum, D. W. Robertson, and J. C. Overpeck.	Glen Hartman, A. F. Vass, and G. H. Starr.

A Partial List of Past and Present Barley Breeders in Foreign Countries

Names of Those Who Have Published Major Papers on Barley Breeding and the Places at Which Some of Their Work Was Done

Bakhteyev, F., Leningrad, Union of Soviet Socialist Republics.
Barbacki, S., Pulawy, Poland.
Beaven, E. S., Warminster, England.
Benes, V., Brunn, Czechoslovakia.
Berg, S. O., Landskrona, Sweden.
Bezradecki, S., Pulawy, Poland.
Biffin, R. H., Cambridge, England.
Bjannes, ———, Moistad, Hjellum, Norway.
Blaringhem, L., Paris, France.
Boeuf, F., Tunis, Tunisia.
Browne, F. S., Lennoxville, Quebec, Canada.
Carne, W. M., Merridin, West Australia.
Champlin, M., Saskatoon, Saskatchewan, Canada.
Clark, J. A., Charlottetown, Prince Edward Island, Canada.
Colin, P., Ottawa, Ontario, Canada.
Cowan, P. R., Ottawa, Ontario, Canada.
Ducellier, L., Algiers, Algeria.
Eikeland, Voll, Moholton, Norway.
Engledow, F. L., Cambridge, England.
Fjaervoll, K., Holt, Tromso, Norway.
Foss, H., Token, Volbu, Norway.
Freistedt, P., Halle, Germany.
Hallquist, C., Landskrona, Sweden.
Harrington, J. B., Saskatoon, Saskatchewan, Canada.
Huber, J. A., Freising, Germany.
Hunter, H., Cambridge, England.
Ikeno, S., Tokyo, Japan.
Imai, Y., Tokyo, Japan.
Jakowski, Z., Poznan, Poland.
Kajanus, B., Landskrone, Sweden.
Karpechenko, George D., Leningrad, Union of Soviet Socialist Republics.
Kiessling, L., München, Germany.
Kuckuck, H., Müncheberg, Germany.
Kwen, S., Kaifeng, Honan, China.
Lamprecht, H. A. K., Landskrona, Sweden.
Larionow, D. K., Kozin, Union of Soviet Socialist Republics.
Laumont, P., Algiers, Algeria.
Lewicki, S., Pulawy, Poland.
Linland, ———, Forus, Norway.
Lods, Emile, MacDonald College, Quebec, Canada.
Lorenz, E., Kloster, Gerode, Germany.
McRostie, G. P., Winnipeg, Manitoba, Canada.
Miege, E., Rabat, Morocco.
Miyake, K., Tokyo, Japan.
Miyazawa, B., Miyazaki, Japan.
Neatby, K. W., Winnipeg, Manitoba, Canada.
Newman, L. H., Ottawa, Ontario, Canada.
Nicolaisen, W., Halle, Germany.
Nilsson, N. H., Svalof, Sweden.
Nilsson-Ehle, H., Svalof, Sweden.
Orlov, A. A., Leningrad, Union of Soviet Socialist Republics.
Peitel, M. J., Derbent, Dagestan, Union of Soviet Socialist Republics.
Peterson, R. F., Brandon, Manitoba, Canada.
Proskowetz, E. von, Kvasice, Moravia.
Regel, R., Leningrad, Union of Soviet Socialist Republics.
Rigo, G., Minsk, Union of Soviet Socialist Republics.
Roemer, T. E., Halle, Germany.
Saunders, C. E., Ottawa, Ontario, Canada.
Scharnagel, T., Freising, Germany.
Schiemann, Eliz., Berlin, Dahlem, Germany.
Sigfusson, S., Brandon, Manitoba, Canada.
Squirrell, W., Guelph, Ontario, Canada.
Summerby, R., MacDonald College, Quebec, Canada.
Takezaki, Y., Kyoto, Japan.
Tedin, H., Svalöf, Sweden.
Tedin, O., Landskrona, Sweden.
Tinney, B. J., Charlottetown, Prince Edward Island, Canada.
Tschermak, E., Vienna, Austria.
Ubisch, G. von, Heidelberg, Germany.
Vavilov, N. I., Leningrad, Union of Soviet Socialist Republics.
Veideman, M., Leningrad, Union of Soviet Socialist Republics.
Vestergaard, H. A. B., Sollested, Denmark.
Vik, K., Aas, Norway.
Wenholz, H., Sydney, Australia.
Wexelsen, H., Hjellum, Norway.
Zavitz, C. A., Guelph, Ontario, Canada.

TABLE 3.—*Genetic studies in barley in the United States*

State and cross	By whom made	Year	Character and ratio	Linkage cross-overs (percent)
California:				
Numerous crosses (parent varieties not given).	K. S. Hor	1924	Wide—narrow outer glumes, 3:1; rough—smooth awn, 3:1; long—short - haired rachilla, 3:1; hulled—naked, 3:1; general—restricted pubescence of outer glumes, 3:1; black—white lemma, 3:1; hood—awn, 3:1; extended—normal outer glume, 1:2:1; dwarf—normal, 3:1; 6-row—non-6-row, 3:1; and 2-row—deficiens, 3:1.	Naked kernel with restricted pubescence of outer glume, 25.3; black lemma with long-haired rachilla, 41.0; smooth awn with long-haired rachilla, 31.6; black lemma with smooth awn, 38.4; and 6-row with extended outer glumes, 40.5.
Chevalier × Abyssinian.	W. W. Mackie	1928	Resistance—susceptibility to rusty blotch, 3 resistant: 1 susceptible.	
Numerous crosses (parent varieties not given).	G. F. H. Buckley	1930	Red—white pericarp, 2 factors; *Rr* factor gave 3:1, purple—white lemma, *Pp* 3:1; purple—white-veined lemma, 3 factors; *Cc* factor, 3:1; blue—white aleurone, *Bl bl* 3:1; 6-row—2-row, a^v a^f 3:1; long-haired—short-haired rachilla, *Ll* 3:1; hood—awn, *Kk* 3:1; hulled—naked, *Nm* 3:1; straight—curved peduncle, *Cr cr* 3:1; black—white lemma, *Bb bR* 3:1; white—orange lemma, *Br br* 3:1; normal—albino seedling, Alb^t alb^t 3:1; complementary genes *Ii* and *Jj* in dominant forms inhibit the expression of *R* and *P*.	Purple-veined lemma with purple lemma, 34.34; purple-veined lemma with red pericarp, 33.73; 6-row with purple-veined lemma, 22.19; 6-row with red pericarp, 16.86; 6-row with purple lemma, 19.38; red pericarp with purple lemma, 0.47; long-haired rachilla with red pericarp, 34.65; long-haired rachilla with orange lemma, 39.11; and hoods with blue aleurone, 40.56.
Manchuria × Deficiens.	G. A. Wiebe	1934	Complementary factors give lethal progeny.	
Atlas × Hanna.	F. N. Briggs	1935	Resistance—susceptibility to mildew, 3:1; susceptibility incompletely dominant.	
Colorado:				
Coast × Hooded	Kezer and Boyack.	1918	Hoods—awn, 3:1	White with xantha seedlings, 4:0.
Coast × Black Hulled.	do	1918	Hoods—awn, 3:1; black glume—white glume, 3:1; and 2-row—6-row, 3:1.	Do.
Colsess I × Colsess IV.	D. W. Robertson.	1929	Green—white seedlings (A^ca^c), 3:1; green—xantha seedlings (X^cx^c), 3:1.	Do.
Colsess I × *distichon nigrinudum*. Colsess I × Minnesota 90-5. Colsess I × Minnesota 90-8. Colsess I × Minnesota 90-5. Colsess I × Minnesota 90-8.	do	1929	Black glume—white glume (*Bb*), 3:1; hoods—awns (*Kk*), 3:1; covered—naked seed (*Nn*), 3:1. Long-haired to short-haired rachilla (*Ss*), 3:1; black glume—white glume (*Bb*), 3:1; hoods—awns (*Kk*), 3:1.	Black glume with hoods, independent. Black glume with covered, independent. Hoods with covered, independent. Long-haired rachilla with hoods, independent. Long-haired rachilla with black glume, independent.
Colsess I × *H. deficiens nudideficiens*.	do	1929	Long-haired to short-haired rachilla (*Ss*), 3:1; covered—naked (*Nn*), 3:1; non-6-row; 6-row (*Vv*), 3:1.	Long-haired rachilla with covered, independent; covered with non-6-row, independent.
Colsess I × *H. distichon nigrinudum*.	do	1929	Non-6-row to 6-row (*Vv*), 3:1; hoods—awns (*Kk*), 3:1; black—white; glume color (*Bb*), 3:1.	6-row with hoods, independent; 6-row with black glume, independent.
Trebi × Minnesota 90-5.	do	1929	Black—white (*Bb*), 3:1; seedlings green—white (A_ta_t), 3:1.	White glume; white seedlings, 22.29.
Colsess I × *H. distichon nigrinudum;* Colsess I × Minnesota 90-5; Colsess I × Minnesota 90-8.	do	1929	Green—white; seedlings (A_ca_c), 3:1; black—white glume; color (*Bb*), 3:1; hoods—awns (*Kk*), 3:1.	White glume; white seedling, independent; hoods with white seedlings, independent.

TABLE 3.—*Genetic studies in barley in the United States*—Continued

State and cross	By whom made	Year	Character and ratio	Linkage cross-overs (percent)
Colorado—Con.				
Colsess I × Minnesota 90-5; Colsess I × Minnesota 90-8.	D. W. Robertson	1929	Green—white seedlings (A_ca_c), 3:1; long-haired to short-haired rachilla (Ss), 3:1.	White seedlings with long-haired rachilla, independent.
Colsess I × *H. distichon nigrinudum;* Colsess I × *H. deficiens nudideficiens.*	do	1929	Green—white seedlings (A_ca_c), 3:1; covered—naked seeds (Nn), 3:1.	White seedlings with covered seeds, independent.
Colsess I × *H. distichon nigrinudum.*	do	1929	Green—white seedlings (A_ca_c), 3:1; non-6-row to 6-row (Vv), 3:1.	White seedlings with 6-row, independent.
Colsess I × Colsess IV.	do	1929	Green—white seedlings (A_ca_c), 3:1; green—xantha seedlings (X_cx_c), 3:1.	White seedlings with xantha seedlings, 4.0.
Colsess I × Colsess V.	do	1930	Green—white seedlings (A_ca_c), 3:1; green—chlorina seedlings (F_cf_c), 3:1.	White seedlings with chlorina seedlings, independent.
Trebi × Colsess V	do	1930	Green—white seedlings (A_ta_t), 3:1; green—chlorina seedlings (F_cf_c), 3:1.	Do.
Coast I × Colsess V	do	1930	Green—xantha seedlings ($X_{c2}x_{c2}$), 3:1; green—chlorina seedlings (F_cf_c), 3:1.	Xantha seedlings with chlorina seedlings, independent.
Coast II × Colsess V.	do	1930	Green—white seedlings ($A_{c2}a_{c2}$), 3:1; green—chlorina seedlings (F_cf_c), 3:1.	White seedlings with chlorina seedlings, independent.
Colsess I × Coast I	do	1930	Green—white seedlings (A_ca_c), 3:1; green—xantha seedlings ($X_{c2}x_{c2}$), 3:1.	White seedlings with xantha seedlings, independent.
Colsess IV × Coast III.	do	1930	Green—xantha seedlings (X_cx_c), 3:1; green—virescent seedlings (Y_cy_c), 3:1.	Xantha seedlings with virescent seedlings, independent.
Colsess I × Coast I	do	1930	Green—xantha seedlings ($X_{c2}x_{c2}$), 3:1; hoods—awns (Kk), 3:1.	Xantha with hoods, independent.
Colsess IV × Coast III.	do	1930	Green—virescent seedlings (Y_cy_c), 3:1; hoods—awns (Kk), 3:1.	Virescent with hoods, independent.
Coast × Colsess V	do	1930	Green—chlorina seedlings (F_cf_c), 3:1; hoods—awns (Kk) 3:1.	Chlorina with hoods independent.
Coast × Lion	do	1930	Branched—unbranched style 63:1; *G.g., G'g', G''g''.*	
Trebi × Minnesota 84-7.	D. W. Roberston, G. W. Deming, and D. Koonce.	1932	Green—white seedlings (A_ta_t), 3:1; green—chlorina seedlings (Ff) 3:1.	White seedlings with chlorina, independent.
Colsess I × Minnesota 84-7.	do	1932	Green—white seedlings (A_ca_c), 3:1; green—chlorina seedlings (Ff), 3:1.	Do.
Coast III × Colsess V.	do	1932	Green—virescent seedlings (Y_cy_c), 3:1; green—chlorina seedlings (F_cf_c), 3:1.	Virescent seedlings with chlorina, 29.3.
Colsess V × Minnesota 84-7.	do	1932	Green—chlorina seedlings (F_cf_c), 3:1; green—chlorina seedlings (Ff), 3:1.	Chlorina seedlings with chlorina seedlings, independent.
Colsess I × Minnesota 84-7.	do	1932	Green—chlorina seedlings (Ff), 3:1; long-haired to short-haired rachilla (Ss), 3:1.	Chlorina seedlings with long-haired rachilla, independent.
Minnesota 84-7 × Trebi.	do	1932	Green—chlorina seedlings (Ff), 3:1; non-6-row to 6-row.	Chlorina seedlings with non-6-row, 18.3±0.74.
Colsess × Minnesota 84-7.	do	1932	Green—chlorina seedlings (F_cf_c), 3:1; hoods—awns (Kk), 3:1.	Chlorina seedlings with hoods, independent.
Colsess IV × Minnesota 72-8.	do	1932	Green—xantha seedlings, (X_cx_c), 3:1; blue-white aleurone, (*Bl. bl.*), 3:1.	Xantha seedlings with blue aleurone, independent.
Colsess V × Nepal	do	1932	Green—chlorina seedlings (F_cf_c), 3:1; long-haired to short-haired rachilla (Ss), 3:1.	Chlorina seedlings with long-haired rachilla, independent.
Colsess × Minnesota 72-8.	do	1932	Hoods—awns (Kk), 3:1; blue-white aleurone (*Bl. bl.*), 3:1.	Hoods with blue aleurone, 22.58±0.82.
Do	do	1932	Blue-white aleurone (*Bl. bl.*), 3:1; long-haired to short-haired rachilla (Ss), 3:1.	Blue aleurone with long-haired rachilla, independent.

TABLE 3.—*Genetic studies in barley in the United States*—Continued

State and cross	By whom made	Year	Character and ratio	Linkage cross-overs (percent)
Colorado—Con.				
Coast × Lion	D. W. Robertson, G. W. Deming, and D. Koonce.	1932	Black—white glume (*Bb*), 3:1; rough—smooth awn *R. r.*, *R.' r.'*, 12:3:1.	Black with rough awn, independent.
Do	do	1932	Black—white glume (*Bb.*), 3:1; branched—unbranched styles, *G. g.*, *G.' g.'*, *G.'' g.''*, 63:1.	Black glume with branched style, independent.
Do	do	1932	Long-haired to short-haired rachilla (*Ss*), 3:1; rough—smooth awned, *R. r.*, *R.' r'*, 12:3:1.	Long with rough awn (*Rr.*), 34.63±1.76.
Do	do	1932	Rough—smooth awn (*Rr*, *R.' r.'*), 12:3:1; branched—unbranched style *Gg.*, *G.' g.'*, *G.'' g.''*, 63:1.	Rough with branched style, indication of linkage.
Colsess V × Nepal	D. W. Robertson	1933	Green—chlorina (F_cf_c), 3:1; covered—naked seed (*Nn.*), 3:1.	Chlorina seedlings with naked, independent.
Colsess V × Chevalier.	do	1933	Green—chlorina (F_cf_c), 3:1; intermedium—nonintermedium (*Ii.*), 3:1.	Chlorina seedlings with intermedium, independent.
Do	do	1933	Intermedium—nonintermedium (*Ii.*), 3:1; hoods—awns (*Kk.*), 3:1.	Intermedium with hoods 15.12±0.65.
Colsess × Black Hulless.	do	1933	Green—white seedlings (A_b a_b), 3:1; hoods—awns (*Kk.*), 3:1.	White seedlings with hoods, independent.
Do	do	1933	Covered—naked seeds (*Nn.*), 3:1.	White seedlings with naked seeds, independent.
Do	do	1933	Long-haired to short-haired rachilla (*Ss.*), 3:1.	White seedlings with naked seeds, 26.
Trebi × Nilsson-Ehle No. 2.	do	1933	Non-6-row to 6-row (*Vv*), 3:1; purple—white straw color (*Pr. pr.*), 3:1; intermedium — nonintermedium (*Ii.*), 3:1.	6-row with purple straw, 9.0±0.68; intermedium with purple straw, independent.
Illinois:				
Wisconsin Pedigree No. 5 × Spartan.	O. T. Bonnett	1929	Tillering—number of tillers not directly controlled by genes; early—late, 3:1; 2-row—6-row, 1:2:1.	
Iowa:				
Velvet × Trebi	J. B. Wentz	1928	Smooth awns—barbed awns, 13:3.	
Glabron × Trebi	do	1928	do	
Minnesota:				
Manchuria × Svanhals and Pyramidatum × Jet.	H. K. Hayes and H. V. Harlan.	1920	Long internode in rachis versus short internode in rachis (1-factor pair difference + modifying factors).	
Hanna × Reid's Triumph.			Long internode in rachis versus short internode in rachis (2-factor pair difference + modifying factors).	
Hanna × Zeocriton	H. K. Hayes and and H. V. Harlan.	1920	Long internode in rachis versus short internode in rachis (3-factor pairs + modifying factors).	
Manchuria × Svanhals.	do	1920	Vulgare versus intermedium versus distichon (2-factor pairs + modifying factors).	
Lion × Manchuria	H. K. Hayes, E. C. Stakman, Fred Griffee, and J. J. Christensen.	1923	Rough versus smooth awn (1-factor pair × modifying factors); black versus white color of glumes (1-factor pair); resistance versus susceptibility to *Helminthosporium sativum* (2-factor pairs).	
Svanhals × Lion	Fred Griffee	1925	Rough versus smooth type of awn (2-factor pairs).	
Do	do	1925	Non-6-rowed versus 6-rowed (*VE*) (*ve*) (*Vv*) and early heading *versus* late heading (*Ee*).	42
			Rough versus smooth awn and resistance to *H. sativum* versus susceptibility.	Rough and resistance. Smooth and susceptibility correlation.

TABLE 3.—*Genetic studies in barley in the United States*—Continued

e and cross	By whom made	Year	Character and ratio	Linkage cross-overs (percent)
Minnesota—Con. SvanhalsXLions.	Fred Griffee	1925	Black versus white color of glume and resistance to *H. sativum* versus susceptibility.	Black and susceptible, white and resistance correlation.
B17 was crossed with B1, B3, and B11.	Adrian Daane	1931	Normal, virescent seedling (*Aa*) (*A V*) (*av*).	28.
			Non-6-rowed versus 6-rowed (*Vv*) (*AP*) (*ap*).	18.
			Black versus white glume color (*Bb*) (*Rs*) (*rS*).	28.
			Hooded versus awned (*Kk*); rough versus smooth awn (*Rr*); covered versus naked caryopsis (*Nn*); long versus short-haired rachilla (*Ss*); purple versus white pericarp (*Pp*).	
Peatland X Glabron.	LeRoy Powers and Lee Hines.	1933	Resistance to *Puccinia graminis tritici* physiologic forms nos. 17, 38, and 49 versus susceptibility to these organisms (*Tt*).	
New York: 2-rowed X 6-rowed.	F. P. Bussell	1921 and later.	2-6, 9:7	
Hulled X Hull-less.	do.		Hulled—hull-less, 3:1.	
Pubescence X nonpubescence.	do.		Pubescence -nonpubescence, 3:1.	
Articulation of rachis X nonarticulation.			Articulated- nonarticulated, 63:1.	
Colored X noncolored flowering glumes.			Colored noncolored, 3 1.	
Hooded X awned.			Hoods—awns, 3:1.	
Awned X awnless.			Awned—awnless, 15.1	
Ohio: Olds White Hull-less (hooded) X Arlington awnless.	L. E. Thatcher	1916	F_1 intermediate-sized hoods; F_2, a graded series ranging from long awns to very short awns and from no lemma appendages through short spurs to large hoods. Interpreted as a dihybrid with incomplete dominance giving 6 fairly distinct phenotypes and 9 genotypes. A dominant factor *H* for hoods: recessive *h* produces awns: *Hh*, intermediate awns: dominant inhibitor *II* strongly suppresses and *Ii* partially suppresses *H* and *h*.	
Wisconsin: Wisconsin Pedigree 5 X Leiorrhynchum.	B. D. Leith	1917	Black-white, 3:1; rough—smooth, 3:1.	

TABLE 4.—*Barley varieties: Estimated acreage and recommended varieties, States*

[Acreage estimated in percentage by State and Federal officials, and computed on the July 1935 forecast by the Division of Crop and Livestock Estimates, Bureau of Agricultural Economics. Varieties the acreage of which is increasing are indicated by +, those decreasing by −]

State	Varieties grown	Hundred acres	Varieties recommended
Arizona	Coast	−284	Vaughn
	Beardless	19	Coast.
	Vaughn	+15	
	Hannchen	+6	
	Trebi	6	
California	Atlas	−6, 501	Atlas.
	Club Mariout	2, 128	Club Mariout.
	Coast	+1, 182	

TABLE 4.—*Barley varieties: Estimated acreage and recommended varieties, by States*—Continued

State	Varieties grown	Hundred acres	Varieties recommended
California	Tennessee Winter	+1,182	
	Hero	+591	
	California 4000	118	
	California Mariout	59	
	Vaughn	59	
Colorado	Trebi	−1,850	Trebi, irrigated.
	Coast, Smyrna, etc	−1,517	Velvet, irrigated
	Colsess	185	Colsess, irrigated.
	Velvet	+74	
	Club Mariout	+74	Club Mariout, dry land.
	Vance Smyrna		Flynn, dry land.
	Flynn		Vance Smyrna, dry land.
			Coast, dry land.
Idaho	Trebi	+1,392	Trebi.
	Coast	−139	Hannchen.
	Hooded	70	Winter Club.
	Hannchen	69	
	Winter Club	35	
	Eastern types	35	
Illinois	Velvet	−276	Wisconsin Pedigree 38.
	Oderbrucker	−180	Velvet.
	Wisconsin Pedigree 37 and 38	+120	
	Trebi, Spartan, etc	24	
Indiana	Oderbrucker	98	Wisconsin Pedigree 38.
	Wisconsin Pedigree	+84	Velvet.
	Spartan	+42	
	Velvet	+42	
	Tennessee Winter	14	
Iowa	Velvet	−4,633	Do.
	Manchuria	−832	Trebi.
	Glabron	+178	
	Trebi	−178	
	Wisconsin Pedigree 37 and 38	119	
Kansas	Stavropol	1,855	Stavropol.
	Coast	445	Manchuria.
	Trebi	371	Odessa.
	Winter	371	Oderbrucker.
	Odessa	+185	
	Manchuria	+185	
	Oderbrucker	+148	
	Hooded	148	
Kentucky	Tennessee and Union Winter	126	Tennessee Winter.
	Kentucky 1	+11	Kentucky 1.
	Tennessee Beardless	3	
Maine	Manchuria & Oderbrucker	30	
	Alpha, Wisconsin Pedigree 38, and Velvet.	30	
Maryland	Tennessee Winter	+204	Tennessee Winter.
	Other varieties, mostly hooded	6	No barb.
Michigan	Spartan	−940	Spartan.
	Oderbrucker	620	Wisconsin Pedigree 38.
	Wisconsin Pedigree 38	+282	
	Michigan Winter	19	
	Black Barbless	−19	
Minnesota	Velvet	+6,912	Velvet.
	Minnesota 184	6,682	Minnesota 184.
	Glabron	4,608	Trebi.
	Trebi	−4,378	Peatland.
	Peatland	+230	Glabron.
	Others	230	Wisconsin Pedigree 38.
Missouri	Tennessee Winter	+240	Missouri Early Beardless.
	Oklahoma Winter	+200	Kentucky 1.
	Tennessee Beardless 5 and 6	100	Tennessee Beardless 5.
	Velvet	25	
	Oderbrucker	25	
	Manchuria	25	
	Trebi	25	
	Missouri Early Beardless	+10	
	Kentucky 1	+10	
Montana	Trebi	−1,104	Trebi, irrigated.
	Horn and Hannchen	460	Horn, dry land.
	Oderbrucker, Wisconsin Pedigree 38, Velvet, and Manchuria.	+147	
	Faust and Himalaya	111	
	Others	18	
Nebraska	Trebi	+1,996	Trebi.
	Mixed	1,640	Glabron.
	Short Comfort	+1,212	Spartan.
	Glabron	+998	Short Comfort.
	Velvet	571	Tall Comfort.
	Tall Comfort	−428	Velvet.
	Spartan	+285	

TABLE 4.—*Barley varieties: Estimated acreage and recommended varieties, by States*—Continued

State	Varieties grown	Hundred acres	Varieties recommended
Nevada	Coast	30	Coast.
	Trebi	30	Trebi.
New Jersey	Velvet	+4	Velvet.
	Winter	+4	
	Alpha, Bon Ami, etc.	−2	
New Mexico	Coast	70	C. I. 4673.
	Unidentified	30	Coast.
	Others	20	
New York	Alpha	1,376	Alpha.
	Wisconsin Pedigree 38	+172	Wisconsin Pedigree 38.
	Other smooth-awned	138	
	Featherston	−34	
North Carolina	Tennessee Beardless 6	84	Tennessee Beardless 6
	North Carolina Hooded	35	North Carolina Hooded.
	Bearded	21	
North Dakota	Manchuria-Oderbrucker+mixtures	−8,330	Manchuria.
	Trebi	5,950	Trebi.
	Manchuria-Oderbrucker	4,760	Oderbrucker.
	Wisconsin Pedigree 38	2,380	Wisconsin Pedigree 38.
	Miscellaneous	1,666	Velvet.
	Velvet	714	
Ohio	do	+128	Do.
	Oderbrucker	−34	
	Winter Barley	+8	
Oklahoma	Oklahoma and Tennessee Winter	825	Oklahoma Winter.
	Manchuria and Oderbrucker	110	
	Coast and others	165	
Oregon (eastern)	Trebi	247	Trebi.
	Miscellaneous	166	Winter Club.
	Club Mariout	124	Flynn.
	Union Beardless	123	
	Meloy	82	
	Hannchen	82	
Oregon (western)	do	384	O. A. C. 7.
	O. A. C. 7	93	Hannchen.
	Others	22	
	Wisconsin Pedigree 38	16	
	Trebi	16	
	Tennessee Winter	11	
	Chevalier	6	
Pennsylvania	Alpha	200	Alpha.
	Wisconsin Pedigree 38	160	Wisconsin Pedigree 38.
	Tennessee Winter	150	Tennessee Winter.
	Tall Comfort	100	Tall Comfort.
South Dakota	Odessa	+9,368	Odessa.
	Trebi	+3,513	Velvet.
	Velvet	+2,342	Wisconsin Pedigree 38.
	Glabron	+2,342	Glabron.
	Others, mostly Manchuria	−2,342	Trebi.
	Ace	−1,171	Horn.
	White Smyrna	−1,171	White Smyrna.
	Wisconsin Pedigree 38	+703	Ace.
	Horn	−468	
Tennessee	Tennessee Beardless 5 and 6	128	Tennessee Beardless 5 and 6.
	Tennessee Winter and Union Winter	42	Union Winter.
			Tennessee 52.
Texas	Tennessee Winter 12,576	+1,212	Tennessee Winter, 12,576.
	Tennessee Winter	−606	Tennessee Winter 643–33.
	Tennessee Winter 643–33	101	
	Others	101	
Utah	Trebi	428	Trebi.
	Utah Winter and others	22	Utah Winter.
Virginia	Union Winter and Tennessee Winter	+256	Tennessee Winter.
	Awnless	61	Union Winter.
	Tennessee Beardless 6	23	
Washington	Beldi Giant	+272	Beldi Giant.
	Blue	−136	Horsford.
	White Winter	−136	White Winter.
	Horsford	+102	
	Others	34	
West Virginia	Tennessee Winter	+32	
	Smooth-awned and hooded winters	+6	
	Manchuria, Oderbrucker, and Alpha	2	
Wisconsin	Wisconsin Pedigree 38	4,630	Wisconsin Pedigree 38.
	Oderbrucker	+3,241	
	Velvet, etc.	+1,389	
Wyoming	Trebi	+742	Trebi, irrigated.
	Horn	228	Horn, dry land.
	Hannchen	20	Odessa, Coast.

Superior Germ Plasm in Oats

By T. R. Stanton, Senior Agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry

WHEN Samuel Johnson described oats as good food—for horses—he meant to satirize the porridge-eating Scot. Nevertheless, the statement is literally true. Those who like oatmeal or oat cakes can bear witness to the fact that no cereal is more palatable. Nor can there be any doubt about its wholesomeness and its economy as a source of fuel for human energy needs. Yet as human food, oats have never competed seriously in any large section of the world with those major cereals for human consumption, wheat and rice. In the United States, for example, less than 4 percent of the oat crop is processed into rolled oats or oatmeal; 96 percent is used for other purposes.

This, however, does not make oats any less important. A similar situation, in fact, holds in the case of corn or maize. Relatively little maize is used directly as food in the form of corn meal—as it was used, for example, by the American Indians and the early colonists. Yet maize is enormously important in the agriculture of the United States, and people consume great quantities of it—in the form of beef, pork, eggs, and poultry particularly. Oats also are converted into energy to be expended by horses in doing work connected with the production of other crops. To the horse, they are what gasoline is to the automobile. In most parts of the world, oats continue to hold their place as an excellent and valuable feed for horses, breeding animals, and young stock.

Usually, then, oats are not grown in this country as a cash crop, that is, to be sold, but for use to feed the animals on the farm. There is another factor, too, that contributes to their usefulness—they fit particularly well into crop rotations as practiced on many farms. Corn or some other row crop—then oats—then grass—then once more corn or another row crop—this is perhaps the most common of all rotation systems. Thus oats in the United States are exceeded in acreage and value only by two other cereal crops—corn and wheat. In Canada, which produces more bushels of oats per capita than any other country in the world, the crop is second in acreage and value to

wheat. Other leading oat-producing areas of the world are the Union of Soviet Socialist Republics, Germany, France, and Poland, in the Northern Hemisphere, and Argentina, in the Southern Hemisphere.

In spite of the fact that they are not directly used as human food to any great extent, oat production bulks large in the world's agriculture. As a consequence, the pressure to produce this cereal as economically as possible, that is, to increase the yield per acre, to minimize the ravages of diseases and insects, and to make the crop adaptable to various areas—this pressure is as great in the case of oats as in the case of any other crop. In other words, though the oat might be considered a humble member of the agricultural family, lacking in the drama and human interest associated with some other crops, yet it is just as important to produce superior germ plasm that will give superior oat plants, aristocrats among oats, as to produce superior germ plasm for wheat or corn or cotton.

The average annual production of oats in the United States for the 5-year period from 1928 to 1932, which may be considered a period of fairly normal production, was 1,241,732,200 bushels. In Canada for the same period it was 399,070,600 (imperial) bushels. The average annual production (bushels) in other leading oat-producing countries for this same period was as follows: Union of Soviet Socialist Republics (European and Asiatic) 978,900,200, Germany 453,184,000, France 329,513,800, the United Kingdom (England and Wales, Scotland, Irish Free State, and Northern Ireland) 206,398,000, Poland 172,216,600, Czechoslovakia 98,015,400, Sweden 78,730,200, Denmark 70,023,200, Argentina 67,402,200, and Rumania 66,264,400. The greatest increase in production in recent years has occurred in the Union of Soviet Socialist Republics. No estimates are available from China. The world production of oats is around 4,500,000,000 bushels annually.

The Botany and Origin of the Oat Plant and Its Distribution

THE oat plant is an annual grass belonging to the genus *Avena*. Cultivated oats are derived chiefly from two species, the common wild oat (*A. fatua* L.) and the wild red oat (*A. sterilis* L.). The principal derivatives of the former are the common oat (*A. sativa* L.), including the side oat (*A. orientalis* Schreb.). Of the latter, the only important cultivated form is *A. byzantina* C. Koch., including *A. sterilis algeriensis* Trabut. Panicles, spikelets, and florets of these groups are shown in figure 1.

Under average conditions, the oat plant produces from three to five hollow stems, or culms, varying from one-eighth to one-fourth inch in diameter and from 2 to 5 feet in height. The roots are small, numerous, and fibrous, and penetrate the soil to a depth of several feet. The leaves average about 10 inches in length and five-eighths of an inch in width. The panicles, or heads, are either spreading (equilateral or treelike) or one-sided (unilateral, horse-mane, or

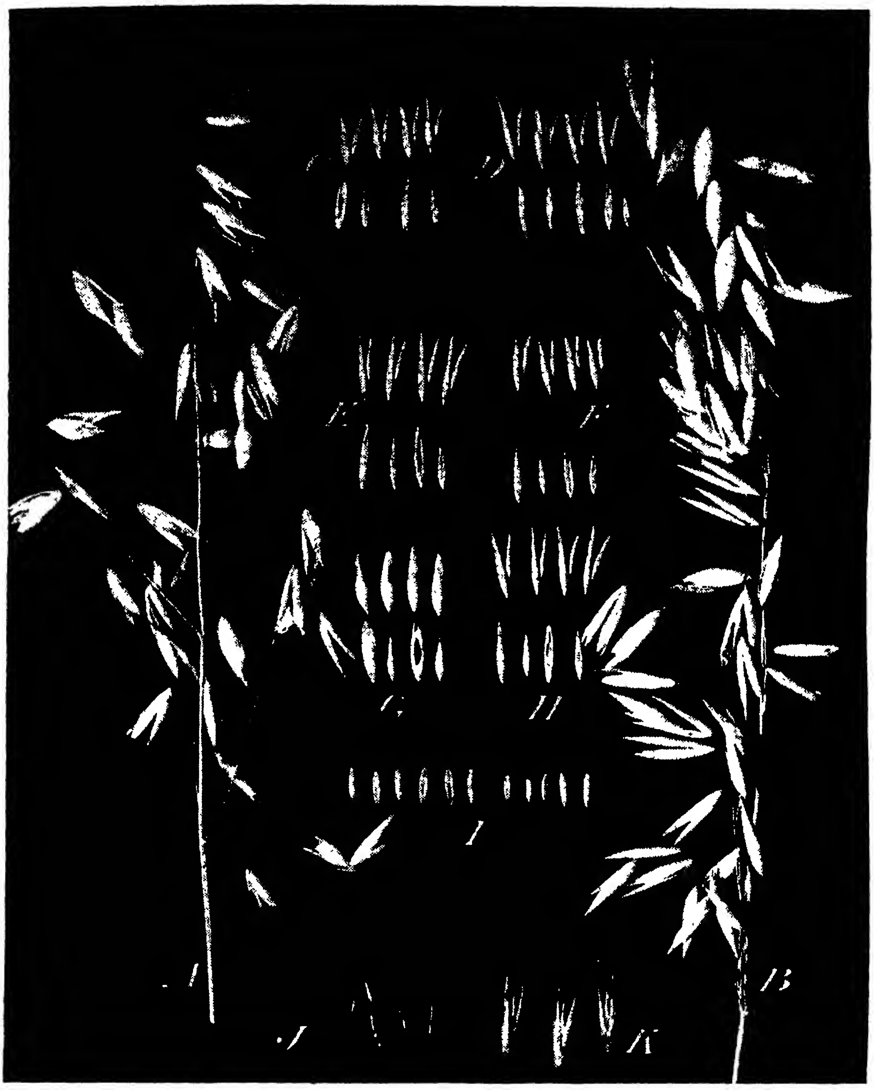


FIGURE 1.—Panicles, spikelets, and florets of oats: (*A*) Equilateral (spreading or open) panicle; (*B*) unilateral (side or horse-mane) panicle; (*C*) common oats; (*D*) red oats; (*E*) long grains; (*F*) short grains; (*G*) plump grains; (*H*) slender grains; (*I*) hull-less or naked oats; (*J*) common wild oats (*Avena fatua* L.), and (*K*) wild red oats (*A. sterilis* L.).

bannerlike). By far the greater number of cultivated varieties are of the type with spreading panicles. The grain is produced on small branches, in spikelets, varying in number from 20 to 150 per panicle. The number of florets or grains in each spikelet, except in the hull-less or naked oat, varies from two to three. The spikelet is loosely enclosed within the outer glumes (chaff). The kernels, except in the hull-less oat, are tightly enclosed within the lemmas or inner glumes and palea. The lemma or hull varies in color from white, yellow,

gray, and red to black and may be awned or awnless. The kernel, or more properly the caryopsis, without its adhering glumes, is very slender, ranging from five to seven sixteenths of an inch in length and from one to two sixteenths of an inch in width. The kernel constitutes about 65 to 75 percent of the total weight of the whole grain.

The origin of cultivated oats, like that of many other economic plants, seems to be lost in obscurity. According to Mal'tzev [1] there is no definite information which would indicate that oats were known to the ancient Chinese, Hebrews, and Hindus. Cato, Cicero, Theophrastus, Ovid, Varro, and other writers of classical antiquity mention oats only as a weed which sometimes was used for medicinal purposes.

The common oat, by far the most important of all cultivated forms, apparently was first found growing in different regions of western Europe. Thence it spread to all parts of the world, wherever the environment was favorable. It was evidently first cultivated by the ancient Slavonic peoples who inhabited western Europe during the Iron and Bronze Ages. However, Mal'tzev believes that the group of oats of the cycle *Avena fatua* L.—the supposed ancestor of *A. sativa* L.—is of Asiatic origin.

Authentic historical information on cultivated oats appears at the beginning of the Christian era. The works of Columella, Dioscorides, Galen, Pliny, and other writers of the early Christian era indicate that one type, the common oat, was grown by Europeans for the production of grain, and another type, the red oat, was grown for fodder, particularly in Asia Minor. Thus the cultivated red oat, now grown in the Mediterranean region and other regions with a warm climate, apparently had its origin in Asia Minor, or west of the Mediterranean. So far, the red oat apparently has not been found anywhere in ancient excavations and hence is considered of more recent origin.

These early writers also mention that oats probably were first found as a weed which infested fields of barley. It appears that originally oats were first widely distributed as a mixture in barley and later domesticated.

Oats were first considered botanically in the sixteenth century. The genus *Avena* appears to have been established by Tournefort in the year 1700. With the work of Linnaeus, one of the greatest systematic botanists of all times, most of the species of oats known today were described by the middle of the eighteenth century.

The various common oats are grown in the cooler and more temperate regions and constitute the bulk of the oats produced throughout the world. The red oats are grown primarily in regions with warmer climates, for example, in the southern United States, the Mediterranean region of Europe and Africa, and Australia. Common oats are poorly adapted to these regions. If it were not for the heat-tolerant varieties of red oats, production of this grain would be of less importance than it is in the warmer countries.

[1] MAL'TZEV, A. I. WILD AND CULTIVATED OATS, SECTIO EUAVENA GRISEB. Bull. Appl. Bot., Genetics and Plant Breeding. Sup. 522 pp., illus. Leningrad, 1930. [Text and additional title and summary in Russian.]

Objectives of the Breeder—How the Work is Done

IN ALL the oat-producing regions of the world the outstanding general problems are higher yield, resistance to lodging, resistance to shattering, and better quality. Breeding for higher yield has received most attention. However, all of these desirable characters constitute a complex which contributes to productiveness.

Many specific problems are peculiar to certain conditions, especially breeding for resistance to the major diseases, such as the rusts and smuts. In the United States, for example, the development of varieties resistant to crown rust is at present a pertinent problem in the Southern States. Likewise, breeding for resistance to stem rust is largely confined to the upper Mississippi Valley States. Owing to the general prevalence of smut in recent years throughout most oat-growing areas in North America, the development of smut-resistant varieties has become a general problem and a rather complex one since the discovery that definite physiologic forms or races of the oat smuts exist. The breeding of drought-resistant sorts for the dry climate of the Great Plains region is also a distinct regional problem. A further example is the development of varieties especially suitable for grazing and forage for regions in which cereal hays are grown. The advancement of the winter oat belt northward by developing varieties of winter oats more resistant to cold than those now available is a specific problem of considerable importance.

INHERITANCE OF CHARACTERS

The mode of inheritance of many major as well as some minor characters in oats is similar to that of the other small grains. Numerous data have been published on the genetics of a wide range of characters of the oat plant.

Matsuura [2] has published one of the most recent and complete monographs and has summarized the results hitherto obtained. He has grouped the character pairs studied into five classes according to their genetic behavior:

(1) Characters controlled by one gene or factor (monogenic). This is the simplest kind of inheritance in hybrids and is commonly known as the 3 to 1 type; for example, in the F_2 generation of a cross between certain black and white oats, three black-seeded plants to one white-seeded are produced. In the case of certain other characters—for example, when naked (hull-less) and ordinary or covered oats are crossed—the F_2 plants segregate, that is, separate proportionally into one naked plant, two intermediate plants (having both naked and covered oats on the same plant or panicle), and one covered plant. This is the 1:2:1 type.

(2) Characters controlled by two genes or factors (digenic). These segregate in a 15 to 1 ratio.

(3) Characters controlled by three genes (trigenic), which segregate in a 63 to 1 ratio.

(4) Characters controlled by four genes (tetragenic), which segregate in a 255 to 1 ratio.

(5) Characters controlled by many genes. When the inheritance of a character, for example a quantitative character, such as height of plant in oats, appears to be governed by many genes, the term multigenic is applied.

[2] MATSUURA, H. A BIOGRAPHICAL MONOGRAPH ON PLANT GENETICS (GENIC ANALYSIS) 1900–29. Ed. 2, rev. and enl., 787 pp. Sapporo, Japan. 1933.

A list of 60 contrasting characters, grouped according to their mode of inheritance as noted by Matsuura, is given in the appendix (p. 379). With this rather complete information, the breeder may proceed with a fairly high degree of certainty to combine, through hybridization, the characters he believes essential for the development of a new and better variety.

Much skill and good judgment are needed, however, to determine which types and classes of segregates should be discarded and which should be retained for further observation and study. When certain varieties are crossed they "nick," as the breeder says, much better than others. This is owing to the combination of desirable genes possessed by the parent stocks. Varieties and strains may differ greatly in performance, that is, in yield, standing ability and so forth, and yet be similar or identical in form. As a consequence, a complete knowledge of the laws of heredity alone is not sufficient for successful oat breeding. Environment also plays a role and must be considered in its relation to the genetic behavior of certain characters. Recombination of characters through hybridization is a phenomenon which frequently leads to unexpected results—and to great benefits for mankind.

METHODS OF BREEDING

The breeding methods for oats are not unlike those described for wheat and barley. The pure-line selection method, in which new progenies are started from the seed of a single panicle or spike, is common to all the small grains, with the exception of rye. Likewise, the hybridization method in oats, in which varieties and strains are crossed to produce variable segregating progenies from which to select, is not different from that in wheat and barley. However, oats are more difficult to hybridize than wheat. The parts of the oat flower are more delicate, and as a consequence they are more easily damaged by emasculation and transfer of pollen. Anthesis or the process of flowering in oats is greatly influenced by temperature and humidity, and these factors must be taken into account if success in hybridization is to be attained.

To those not familiar with plant-breeding methods, the development of new varieties of oats may seem a slow process. In the case of improvement by pure-line selection, ordinarily only 1 year is required to isolate lines for advancing to nursery tests, where further observations on resistance to disease, lodging, and so forth, and actual determinations of yielding power are made. As a rule, preliminary nursery yield tests require from 1 to 3 years. This is followed by a more advanced nursery test with a greater number of replications or repetitions of the plots or rows, which requires from 3 to 5 years. When a new strain has proved itself in nursery trials, it is usually given a further test in larger field plots for 2 to 5 years. After it has demonstrated superiority to standard varieties in both nursery and field plots, a year or two more is necessary for multiplication of seed for distribution to farmers. Altogether, these operations total 8 to 16 years.

Homozygous or true-breeding selections from hybrids require about the same time for proving their value. However, anywhere from 3 to 10 years may be needed to purify hybrid populations to

FIGURE 2.—Portion of a cooperative oat-breeding nursery at Ames, Iowa, 1935, with ten thousand 5-foot rows. The destructive effect of heavy artificially and naturally produced epiphytotics of crown and stem rust are shown. Range A (left), segregates from a Magistral × Iogold cross with high resistance to both stem and crown rust; ranges B and C (left to right), uniform rust nursery in foreground and uniform smut nursery in background, consisting mostly of varieties susceptible to one or the other rust; range D (right), segregates from an Anthony × Bond cross with high resistance to both rusts.

make available true-breeding lines for performance studies on yield, quality, and so forth. Sometimes reselection is necessary to obtain homozygosity or uniformity in all readily observable characters. In recent years the advancement of hybrid populations has been greatly facilitated by growing two generations each year, one in the greenhouse and one in the field. The development of smut and rust infection by artificially inoculating seed and plants under both field and greenhouse conditions for the rapid elimination of the susceptible segregates in hybrid populations also has greatly speeded up breeding operations (fig. 2).

Many vicissitudes beset the oat breeder. Frequently, especially in the hybridization method where special emphasis is placed on some outstanding desirable character—as resistance to a particular disease—new strains highly resistant to this disease are obtained but fail to produce satisfactory yields or lack some desirable character such as standing ability. In the future, emphasis must be placed on the development of a complex of desirable pathological, physiological, and agronomic characters and qualities if success is to crown the efforts of the oat breeder. Under no circumstances, practically speaking, can the breeder afford to overlook the adaptability and suitability of the variety for commercial production.

Persistence and patience are usually the greatest assets for success. The development of better varieties of oats or of any other crop plant is a long-time effort. This is especially true if real advances are to be made in productiveness, disease resistance, better quality, stiffer straw, and other valuable economic characters.

Achievements in Oat Breeding in this Country and Abroad

NORTH AMERICA

PRIOR to the initiation of oat breeding or improvement by th State agricultural experiment stations and the United State Department of Agriculture, many so-called new varieties wer exploited each year by commercial seedsmen. Stocks of seed wer imported from Europe and grown in private test gardens for a yea or two and then offered to the trade as wonderful new varieties By this system some superior but also much inferior germ plasn was obtained and distributed. A few seedsmen improved their stock by mass selection. The annua reports of the United State Commissioner of Patents, prio to the organization of the De partment of Agriculture, con tain references to the importa tion of new varieties of oats and their distribution to the American farmer.

FIGURE 3.—The late Cyrus G. Pringle, of Charlotte, Vt., a pioneer American oat breeder, who originated Pringle Progress and other varieties by hybridization and subseqeunt selection. He also bred several important varieties of hybrid wheats.

The first hybridizer of oat varieties in this country appears to have been Cyrus G. Pringle, of Charlotte, Vt. (fig. 3). He originated several varieties, of which Pringle Progress, first distributed in 1875, was the most important in its day. It was a selection from a cross of Excelsior, a midseason white variety, and Chinese Hull-less, a naked oat which was widely exploited as a valuable new oat during the last half of the nineteenth century. It is claimed that Pringle American Triumph, developed by Pringle from a cross between the Excelsior and Waterloo varieties, was a very productive oat at one time, but it never attained the popularity of Pringle Progress.[3]

Systematic pure-line selection and progeny tests of oats in the United States were first started by Willet M. Hays, at the Minnesota Agricultural Experiment Station, St. Paul, in 1888.[4]

During recent decades attention has been concentrated on pure-line selection and hybridization, and the application of these methods

[3] John Garton, of Newton-le-Willows, Lincolnshire, England, a private or commercial breeder, developed many new oat varieties by hybridization.

[4] In Europe, pioneers in the application of this method to oat breeding were Louis de Vilmorin, F. Hallet, N. Hjalmer Nilsson, and others.

has resulted in many superior varieties. The rate of development has been in direct proportion to progress in the determination of the fundamental principles of genetics and the laws of heredity, and the perfecting of breeding methods and technique. The application of improved breeding methods, based on definite genetic facts, has itself served to stimulate interest in the development of better varieties.

A summary of the information on the history, development, value, and so forth of the improved varieties in the United States and Canada, as given in the returned questionnaires on superior germ plasm in oats, is shown in table 2 (p. 381). A special effort has been made to tabulate the information in as concise and simple a form as possible, thus making available to breeders a catalog of superior germ plasm as found today in improved varieties now grown on farms.

According to the results presented in table 2, oat improvement by breeding in North America has been almost entirely the work of the agricultural experiment stations of the United States and Canada, and the United States and the Dominion of Canada Departments of Agriculture. An outstanding private breeder of better oats is the Coker's Pedigreed Seed Co., Hartsville, S. C. Another private breeder is the Ferguson Seed Farms, formerly of Sherman, Tex., now of Howe, Tex. However, their work has been influenced by suggestions and material furnished by cereal breeders of the State agricultural experiment stations and of the United States Department of Agriculture.

Agronomists, botanists, plant breeders, and geneticists have all made definite contributions toward the development of superior varieties. Many of the most successful breeders have been those with training in agronomy, botany, plant breeding, and genetics. The names of the oat breeders in North America are given in table 2 in connection with the varieties they have developed.

Superior Varieties in Commercial Production

The improved varieties now of commercial importance shown in table 2 have contributed toward an increase in production per acre, and improved quality, of oats grown in the United States and Canada. Varieties representing mixed populations, some of which were grown commercially for years, supplied much of the parent material from which the improved strains were evolved by selection, but all the original types were brought from abroad, mainly from European sources, at one time or another.

The improved varieties originating in the confines of the United States are shown in figure 4.

Space prevents comment on the relative value of each variety included, but it is worth while to treat several improved varieties together when they have evolved from a common ancestor.

Modern Descendants of Various Ancestors

Fulghum, which was originated some years ago on the farm of J. A. Fulghum (fig. 5), in southeastern Georgia, is a good example of a variety that belongs in such a group. Mr. Fulghum was

FIGURE 4.—Improved oat varieties in commercial or farm production in the United States. Kherson is an important introduction by the Nebraska Agricultural Experiment Station. Sixty-Day, Swedish Select, and Victory, outstanding introductions by the United States Department of Agriculture, are widely grown and cannot be credited to any particular State.

walking through his field of Red Rustproof oats one Sunday morning and noticed a plant that was taller and earlier than those surrounding it. He harvested the plant individually and increased the seed from it. This gave rise to all the Fulghum oats now grown in the United States. At present, Fulghum, together with its strains, is the most important varietal type of red oats grown in this country. Earlier maturity, a more vigorous plant development, fewer awns, and a quality of grain better than that of Red Rustproof have given Fulghum its high place. Alabama Fulghum No. 321, Kanota, Franklin, Frazier, and the Coker and Marett Fulghums constitute the group of improved strains of Fulghum now grown commercially. Kanota is grown extensively as a spring variety in Kansas.

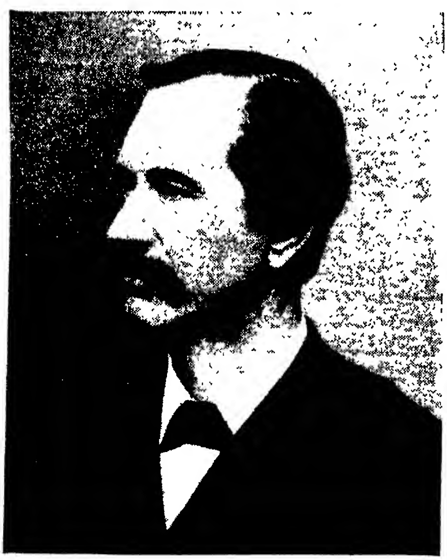


FIGURE 5.—J. A. Fulghum, a pioneer farmer-breeder of Warrenton, Ga., who selected and developed Fulghum, a distinctly American oat, which with its strains, such as Kanota, Frazier, Franklin, and others, represents the most important varietal type of red oats grown in the United States.

The improved strains of Red Rustproof are Alabama Red Rustproof No. 740, Coker Appler No. 3, Ferguson No. 71, Ferguson No. 922, and Nortex. Ferguson No. 922 and Nortex are widely grown in Texas. Ferguson No. 71 has been almost entirely replaced by Ferguson No. 922.

Brunker and Columbia represent the only two improved strains of Burt included in table 2. Brunker is a very early, uniform strain, especially well adapted for growing on the dry-land farms of northeastern Colorado. Columbia also is very early. It is similar to Burt but was selected from Fulghum. It is rapidly attaining commercial importance in Missouri and in parts of Illinois and Indiana.

The various strains and selections of Kherson and Sixty-Day represent the most important group of early common oats grown in the United States. They contribute materially to the wealth of the Corn Belt section every year. The original Kherson and Sixty-Day are early, productive, and drought-escaping varieties. Almost immediately upon introduction, they became widely grown in the Corn Belt, where, owing to the high nitrogen content of the black, rich prairie soils, the later and larger midseason varieties were not satisfactory. However, they constituted mixed populations, and for this reason they have been the progenitors of many superior strains of American oats. The original varieties formerly were grown extensively on farms but have been replaced largely by the improved varieties developed from them.

FIGURE 6.—L. C. Burnett, one of the most successful breeders of improved varieties of oats by the pure-line selection method in the United States. At the Iowa Agricultural Experiment Station, in cooperation with the Bureau of Plant Industry, United States Department of Agriculture, he developed the improved varieties Albion (Iowa No. 103), Iowar, Iogold, Iogren, and Richland (Iowa No. 105). Iogold and Richland are especially outstanding because of high resistance to stem rust. Burnett also has developed improved wheat varieties for Iowa.

The selections made by L. C. Burnett (fig. 6), one of the older and more successful oat breeders in the United States, at the Iowa Agricultural Experiment Station, are particularly noteworthy, especially Richland and Iogold, because of high resistance to stem rust. Gopher has been valuable in Minnesota and probably represents the stiffest-strawed strain selected from Kherson or Sixty-Day. State Pride, grown extensively in Wisconsin, produces a straw taller than that of any other Kherson oat. Other improved strains of Kherson and Sixty-Day are Albion (Iowa 103), Iowar, Nebraska No. 21, Cole, and White Cross. The latter was developed from a cross of Wisconsin No. 2 on Sixty-Day. Briefly, the Kherson and Sixty-Day varieties embrace some of the best oat germ plasm ever introduced into North America.

Among the outstanding improved midseason varieties with white grains are Colorado No. 37, Maine No. 340, Wolverine, Anthony, Ithacan, Upright, Wayne, Wisconsin Wonder, Forward, and Spooner. Colorado No. 37 deserves especial mention because of its stiff straw, high grain quality, and general suitability for growing under irrigation. Maine No. 340 is the leading variety in Maine. Wolverine (fig. 7), a stiff-strawed, highly productive variety, is extensively grown in

Michigan. Anthony is replacing the old White Tartar or White Russian oat in stem rust areas, but high susceptibility to smut is a decided disadvantage. Ithacan and Upright, because of excellent standing ability and good grain quality, are proving valuable on dairy farms in New York, although Cornellian, a very productive, gray-seeded variety, is decidedly the most important commercially (fig. 8). Wayne is a high producer in Ohio, while Wisconsin Wonder and Forward are standard in Wisconsin. Wayne is the leading improved variety grown in northern Ohio and probably represents the most important hybrid variety now grown commercially in North America.

Swedish Select, Victory, and Golden Rain—the latter two reported from Sweden—are excellent examples of introduced improved varieties developed in other countries that have found an important place in American agriculture without further selection or improvement. Swedish Select also ranks high among the more important introductions into the United States. However, Victory is proving to be somewhat more desirable on the basis of both yield and quality, and consequently is replacing Swedish Select.

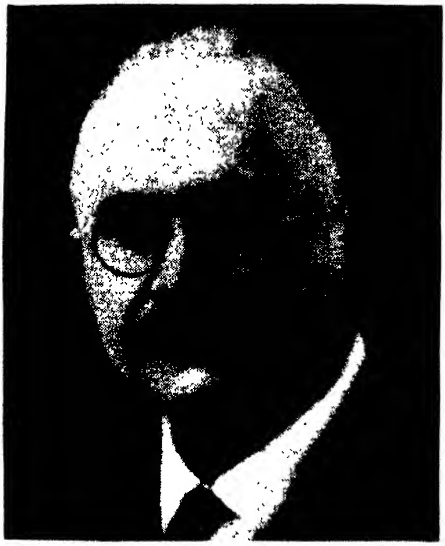


FIGURE 7.—The late Frank Azor Spragg (1874–1924) was one of the successful plant breeders of the United States. He was a member of the staff of the Michigan Agricultural College and the Michigan Agricultural Experiment Station from October 1906 until his death in August 1924. During this period he selected and developed the Alexander, Wolverine, and Worthy oat varieties. He also developed improved varieties of wheat, barley, alfalfa, and beans.

Markton is decidedly the most important of the improved midseason varieties with yellow grains because of its great productiveness and high resistance to the smuts of oats. Owing to these very desirable characters, Markton is being used extensively as a parent in hybrids for the development of varieties resistant to a combination of diseases. Markton has not been satisfactory in the Corn Belt because of high susceptibility to stem and crown rusts. Other excellent strains of this group deserving special mention are Rainbow and Patterson. Rainbow, with its high resistance to stem rust and its high yield is one of the best lines isolated from Green Russian. Patterson is a very productive, thin-hulled variety grown extensively in Pennsylvania.

The improved varieties developed primarily for fall seeding are Lee, Support, Coker Norton No. 3, Coker No. 33–50, Coker No. 33–1, Coker No. 33–47, and Coker Fulgrain No. 33–19. Lee is a hardy hybrid winter oat best adapted to Virginia, North Carolina, and Arkansas, where it may replace the old Winter Turf or Virginia Gray variety. However, its high susceptibility to smut infection is undesirable. Support is attracting the interest of farmers in western Oregon, where it is a very satisfactory variety for growing with annual viny legumes. Of the Coker productions, Fulgrain No. 33–19 is

probably the most promising. Tech, a high-yielding variety developed in Virginia, has not become popular because of its black grains.

The various strains of Banner represent the most important varietal type of oats grown in Canada. The high yield and quality of Banner has made it a favorite in many Provinces of the Dominion. O. A. C. No. 72 and O. A. C. No. 144 are other leading varieties, especially in Ontario. Cartier, a variety maturing somewhat earlier than Banner, is of much promise in some sections of Canada. Laurel and Liberty are not of much importance commercially because they are hull-less varieties, although they should be cited as new varieties of hull-less oats much superior to the old Chinese Hull-less. This is evidence that even hull-less oats may be improved by breeding.

Older Varieties Still in Use

Several of the older varieties still grown extensively in the United States and Canada are not included in table 2, as little information is available concerning their breeding and development. However,

> *THE development of better varieties of oats or of any other crop plant is a long-time effort. Persistence and patience are usually the best assets for success. As a rule, preliminary nursery tests require from 1 to 3 years. This is followed by a more advanced nursery test, which requires from 3 to 5 years. When a new strain has proved itself in nursery trials, it is usually given a further test in larger field plots for 2 to 5 years. After it has demonstrated superiority to standard varieties in both nursery and field plots, a year or two more is necessary for multiplication of seed for distribution to farmers. Altogether, these operations total 8 to 16 years.*

these varieties represent superior germ plasm because of the place they continue to occupy in American agriculture and must not be ignored in this summary of oat improvement. Silvermine, Banner, Green Russian, and White Tartar (White Russian), as well as Red Rustproof and Burt, grown as original varieties in the southern half of the United States, belong in this category.

The best available information indicates that the original Silvermine, grown under various names through the years, was introduced to the seed trade in the late nineties by the John A. Salzer Seed Co., La Crosse, Wis., as a promising new variety. There is no definite information on its origin and selection.

Banner was first placed on the market in the United States as American Banner by James Vick, seedsman, Rochester, N. Y., in 1886. It is said to have been an old renamed oat, originated from a

very small lot of seed. The value of Banner selections in Canada has been referred to in previous paragraphs. There seems to be no recorded history of Green Russian. It probably was first introduced into the upper Mississippi Valley States in the seventies or eighties by colonists from northern Europe. Various selections from Green Russian have shown high resistance to stem rust and some resistance to crown rust. The greatest center of production of the Green Russian type of oats has been in northwestern Iowa.

The history of White Tartar (White Russian) also is not clear. It is a side oat and an inferior yielder but persists in certain sections because of high resistance to stem rust, a fact that has been known in the United States for at least 50 years. White Tartar has been used extensively by the Minnesota Agricultural Experiment Station in breeding experiments for the development of stem rust resistant varieties with spreading panicle, earlier maturity, higher yield, and better quality.

Little is known regarding the introduction of the original Red Rustproof variety into the South. One of the best-known mass strains of Red Rustproof today is Hastings Hundred Bushel. Other mass strains of the variety are Texas Red and California Red. Named strains, of less importance than formerly, are Appler and Bancroft.

Burt is said to have been originated about 1878 as a selection from a field of Red Rustproof in southern Alabama. Today much of the original commercial Burt is exceedingly variable and appears to be a mixture of several varietal types. Coastblack, a variety grown extensively but exclusively in the coastal sections of California, is another variety with black grains belonging to the red oat group. There is little definite information concerning its origin, except that it evidently came into existence as a selection from Red Algerian, Red Rustproof, or California Red.

Schoolmam and Three Grain, varieties of midseason common oats, the origin of which is undetermined, are being recommended for growing in Oregon. Schoolmam, a mass strain of the Green Russian type with tall straw, was collected by the United States Department of Agriculture in north-central Iowa several years ago. A lady school teacher, for whose profession it was named, apparently first brought this oat to Iowa from Michigan about 30 years ago. Schoolmam is still grown to some extent in northern Iowa. Three Grain probably was first introduced for growing on farms of Oregon by a seed dealer in Albany, Oreg.

Many more of the older named varieties of American oats could be enumerated. However, they are obsolete and of historical interest only. They no longer represent superior germ plasm and therefore are not altogether germane to the purpose of this summary.

New Superior Stocks Available

As indicated previously, it requires from 8 to 16 years to produce and prove a new variety of oats. As a consequence, there are in process of development numerous promising new selections and lines, some of which have been named and are about ready for distribution. Other lines have not been named, and still others may never be, because of low yield and undesirable grain characters. A decade from

now, many of these new strains which prove of agronomic value will have replaced the varieties listed in table 2. The large number of superior strains reported is a fairly accurate index of the varied nature and comprehensiveness of the hybridization experiments now in progress.

Information relative to the history, origin, development, and potential value of the superior new stocks now available in the United States and Canada is given in table 3. Many of these new strains are still designated only by a number. Some of the older lines that have not attained, and may never attain, commercial production have been included because they possess one or more especially desirable characters of breeding value—for example, high resistance to disease and low temperatures or excellent grain and straw characters.

In most cases the institutions reporting superior strains are also those which have developed the improved varieties that are now in commercial production. However, there have been changes in personnel in the course of the years, and as younger and better trained men have applied the latest developments in genetics and plant breeding technique, it has been possible to consider and recognize smaller differences in yield, quality, and other characters, which are of cumulative importance for a crop grown on a large scale. Recent advances in knowledge of plant pathology and plant physiology also have materially expedited oat breeding.

FIGURE 8.—H. H. Love, professor of plant breeding, Cornell University, Ithaca, N. Y., since 1908, has made substantial contributions to oat improvement in the Northeastern States. Cornellian, Ithacan, and Upright are the most important of the improved varieties developed under his direction.

A Reservoir of Superior Germ Plasm.

The survey summarized in the appendix indicates that a reservoir of superior germ plasm in the form of so-called elite or superior stocks of oats is being accumulated in North America through the processes of introduction and breeding. The recent introduction and development by hybridization of varieties and strains resistant to certain destructive plant diseases, such as rust and smut, have added greatly to the value of present stocks. The introduction of superior indigenous and other material has furnished parent stocks from which productive strains also have been isolated by pure-line breeding. However, of the lines shown in table 3 more than 50 percent were selected from hybrids. This is especially true where breeding for disease resistance is an important objective. Many of the superior varieties originating mostly from pure-line selection listed in table 2 are the parents of the new strains shown in table 3. The latter will in turn provide new breeding stock for the development of still more productive stocks in the future.

In discussing the present and potential value of these lines, it is not possible to treat them all individually.

In Alabama, Red Rustproof No. 43a and Fulghum No. 6a, which are superior strains of the respective varietal types, have been developed. The term "late ruster" as applied to Red Rustproof No. 43a indicates that crown rust infection does not seriously retard the growth of the variety until rather late in the period of plant development. Most strains of the Red Rustproof (Red Texas) oat that are or have been of economic importance in the South have this quality. Hence the name "Rustproof" was applied to this type of oats many years ago.

At Fayetteville, Ark., several strains of the Culberson type with high winter resistance and high yield have been isolated.

Of the superior strains developed at the United States Dry Land Field Station, Akron, Colo., Trojan and Edkin are the most outstanding, although neither has been of economic importance. Trojan is a very early white variety with excellent straw and resistance to smut, but under most conditions it is too early to be very productive. Edkin, a Kherson selection highly resistant to stem rust and very productive, has not been distributed for growing on farms. When the high stem rust resistance of Edkin was discovered in 1925, Richland, a variety with similar desirable characters, previously described under superior varieties, had already been distributed in 1914 for growing on farms in Iowa. Furthermore, Iogold, another oat of the same type, perhaps slightly superior to either Edkin or Richland, was about ready for distribution. Under these circumstances, it did not seem advisable to distribute Edkin, a third variety of similar characters, for commercial production.

At Experiment, Ga., strains from crosses of Markton × Red Rustproof are showing high yield, winter resistance, and moderate resistance to smut. As a parental variety in a hybrid, Markton apparently transmits unusually high yielding power to its progeny. The improved strains, Alber and Berger from Uruguay, which have been tested at Tifton, Ga., and other experiment stations in the South, offer superior germ plasm as red oat varieties resistant to certain physiologic forms of crown rust occurring in that region and may prove valuable in a program of breeding for crown rust resistance in red oats.

Many of the smut-resistant hybrid selections of midseason white oats resulting from the cooperative breeding experiments at Aberdeen, Idaho, are rather promising. The objective in crossing Markton on Idamine, Victory, Swedish Select, etc., to combine the high smut resistance and great productiveness of Markton with the desirable grain characters of the best midseason white varieties, has been attained to a high degree in these new lines. Some of the most promising, including those with white grains, that have continued to show high resistance to the smuts of oats and have produced excellent yields are given in table 3. Ultimately only one or two of these lines may be distributed for production on farms, but it is too early to indicate definitely which strains will eventually be chosen. Their breeding has demonstrated the fact that through hybridization the desirable characters of different varieties may be brought together for the development of a still better oat plant.

The group of new lines now in process of development in the cooperative oat experiments in Iowa are of genetic and economic interest,

especially those in which high resistance to the smuts has been combined with high resistance to the rusts.

The strains arising from crosses of Markton on Iogold, Iowa No. 444, and so forth, may be considered as a group. The hybrids from which these strains were selected were made by F. A. Coffman before the Victoria and Bond varieties, with their high resistance to crown rust, became available. Some of these lines, therefore, possess only the moderate crown rust resistance of Iowa No 444 and Rainbow. These varieties apparently are resistant to certain physiologic forms and not to certain other forms, which are present in some seasons and not in others. However, the high resistance of the Markton × Iogold lines to the races of smut found in the Corn Belt, and to stem rust, combined with the high productiveness of Markton, make them of potential promise as new varieties for the Corn Belt. The 12 lines shown in table 3 will be grown by L. C. Burnett in replicated field plots at Ames, Iowa, in 1936.

Wealth of Material from Hybrid Selections.

The second large group of new, early, disease-resistant strains include the various selections from the cross of Victoria × Richland. The lines shown in the appendix have been among the most promising of a relatively large number, especially with regard to resistance to the smuts and rusts. The high crown rust resistance and smut resistance of Victoria and the stem rust resistance and excellent grain characters of Richland appear to have been combined in a satisfactory manner in these lines. The development of these interesting lines, particularly the combination of resistance to the smuts and the rusts in hybrids, has recently been reported.[5]

Forty-eight of the Victoria × Richland lines were tested for yield in single 15-foot rows for the first time at Ames, Iowa, in 1935, with excellent results, indicating that they may not lack productiveness. Some of these lines already have been used by F. A. Coffman in numerous new multiple hybrids, in which they were crossed back on Richland, Iogold, Markton, Carleton, and so forth, and on other hybrid lines, especially those referred to above from crosses of Markton × Iogold, Markton × Iowa No. 444, and others.

Neither Victoria nor Bond is proving of value in itself for growing on farms. Victoria is too late and too heavily awned and lacks adaptation or agronomic value. Bond is also late but possesses better grain and straw characters than Victoria. Bond showed unusual ability to resist adverse conditions at many experiment stations in the uniform rust nurseries of 1935.

Promising lines have been isolated from a Bond × Iogold cross by H. C. Murphy at Ames. One of these lines is shown in table 3. In Iowa Nos. 438 and 1317, L. C. Burnett has developed two strains suitable for a wide range of sowing dates. Iowa No. 1256 has produced high yields from late seedings; it is a desirable variety to sow when spring seeding is delayed by wet weather or other causes. The Russian selection No. 76 has been observed in special nurseries for several years both in the United States and Canada, but no fatuoids—to be discussed later in this article—were found. Hajira has shown high resistance to stem rust but lacks productiveness and

[5] STANTON, T. R., MURPHY, H C, COFFMAN, F A, and HUMPHREY, H B DEVELOPMENT OF OATS RESISTANT TO SMUTS AND RUSTS (Phytopath Note) Phytopathology 24 165–167 1934

standing ability. Magistral, a variety with side panicle, has shown resistance to both rusts. It is rather late in maturity but has fair grain characters.

In the cooperative breeding work at Manhattan, Kans., special emphasis is being placed on the development of Fulghum-type strains resistant to the Fulghum races of smut. Kansas selection No. 6136 (C. I. 3220) has been of promise, although it has shown only moderate resistance to the Fulghum smuts. The two Fulghum selections H. C. No. 726 and H. C. No. 713 are more uniform in plant characters and probably produce fewer fatuoids and other aberrants than the original Fulghum. However, as yet no absolutely true-breeding strains of typical Fulghum oats have been isolated. At East Lansing, Mich., one of the lines from the Markton × Victory cross sent from Aberdeen, Idaho, to the Michigan Agricultural Experiment Station in 1929, is of much promise for Michigan conditions. Tula, introduced by the Department of Agriculture from the Union of Soviet Socialist Republics, a variety of unusual grain quality, has been attracting the attention of the oat breeders at East Lansing. Tula may prove of value for breeding oats of better quality.

In Mindag, H. K. Hayes of University Farm, St. Paul, Minn., has developed a promising new stem rust resistant variety. It is high yielding and also has resistance to the physiologic forms of the smuts that attack varieties of oats grown in the Northern States. Several strains of Burt isolated by T. A. Kiesselbach, of the Nebraska Agricultural Experiment Station, have shown resistance to stem rust and high yielding ability at Lincoln. At New Brunswick, N. J., some Fulghum lines have been isolated that are resistant to lodging and produce high yields of both grain and straw. In the Eastern States oat straw is relatively valuable for feed and litter purposes, hence varieties are wanted that are high producers of both grain and straw.

From South Carolina to Saskatchewan.

In the cooperative breeding investigations at Cornell University, Ithaca, N. Y., two new hybrid lines have been developed, special attention being given to high yield, thin hull, and smut resistance in a hull-less oat. In Ohio, hybrids on Fulghum have resulted in lines that are superior in color. Several cold-resistant lines of winter oats selected from crosses supplied from the Arlington Experiment Farm, Rosslyn, Va., in 1926, have shown promise from fall seeding at Stillwater, Okla.

The Coker's Pedigreed Seed Co., Hartsville, S. C., has bred numerous new smut-resistant strains of fall-sown red oats from a hybrid combination of Norton Strain No. 20–93 (also known as Big Boy) and Navarro. Three of the potentially most promising lines from this cross are listed in table 3. The breeders at Hartsville in their improvement program are also emphasizing the importance of combining the desirable characters of Fulghum with smut resistance and winter resistance. So far, the Navarro variety has proved valuable as a source of basic resistance to the Fulghum races of smut. George J. Wilds, head plant breeder for Coker's Pedigreed Seed Co., is enthusiastic about the value of Navarro for this purpose.

Matthew Fowlds, of the South Dakota Agricultural Experiment Station, has succeeded in developing South Dakota No. 165, a high-yielding smut and stem rust resistant hull-less oat by hybridizing several varieties.

At Knoxville, Tenn., lines with high winter resistance have been isolated as reselections from a Fulghum—winter type, No. 699–2011—selection sent to Knoxville a few years ago by the Division of Cereal Crops and Diseases for testing for yield, quality, etc. These Tennessee selections probably are among the hardiest strains of winter oats now available in the United States. If they do not prove of value for growing on farms, they should prove valuable for breeding purposes.

Higher yielding and more uniform strains of the Red Rustproof variety have been developed by the Texas Agricultural Experiment Station at substation no. 6, at Denton. Navarro, a distinct variety of *Avena byzantina*, highly resistant to the smuts of oats, was offered for sale some years ago as a novelty by the Ferguson Seed Farms, then of Sherman, Tex. It was obtained by A. M. Ferguson from a friend in Navarro County, Tex. Little information is at hand relative to its origin, but it probably came into existence as a natural hybrid between Red Rustproof and some variety of northern oats. As already indicated, it has proved a most valuable variety for use in crosses for the breeding of smut-resistant red oats of the Fulghum type. However, it has not become of any commercial importance because of low yielding ability.

In Virginia, at the Arlington Experiment Farm, a group of new strains with winter resistance has been developed. Custis, a sister hybrid selection of Lee, has been high in yield with excellent grain quality. However, as in the case of some improved strains of spring oats, it did not seem advisable to distribute Custis in addition to Lee and thus confuse the two varieties on the farm. Hairy Culberson is a reselection from a strain of oats isolated by C. W. Warburton at College Park, Md., in 1907 from a commercial lot of Culberson. Though not so productive as some other winter varieties, Hairy Culberson has been outstanding for winter resistance at several stations in the South. The young plants are covered with numerous short setaceous or bristlelike hairs, hence the name. Whether or not these hairs are correlated with winter resistance has not been determined. Culred, an oat originating from a hybrid made many years ago by J. B. Norton, also has been outstanding for cold resistance but is somewhat deficient in yielding power. It belongs to the red oat group (*Avena byzantina*), but the grains are grayish white and not reddish as in Fulghum and Red Rustproof.

The group of strains representing winter types of Fulghum are of special interest because they have shown much more winter resistance than the original Fulghum oat. The origin of the three strains listed in table 3, namely, those with selection nos. 699–202, 699–2011, and 699–2015, along with other similar strains, have been reported by Stanton.[6] The strain 699–2011 (C. I. 2499) from the beginning showed considerable variability in plant characters. At the suggestion of the writer, a group of reselections was made from it and sister selections at the Arlington Experiment Farm in 1926 by F. A. Coffman and J. W. Taylor. Some of these reselections are more uniform in plant characters and probably more productive. However, no apparent improvement in winter resistance was made by reselection. All these Fulghum (winter type) selections are very susceptible to

[6] STANTON, T. R. BREEDING WINTER OATS FOR THE SOUTH. Jour. Amer. Soc. Agron. 18: 804–814, illus. 1926.

the rusts of oats and the Fulghum races of smut. However, they offer germ plasm for the development of hardier red oats, a problem of considerable economic importance.

Though lacking winter resistance, Aurora is deserving of mention for breeding because of high yield, desirable straw, and excellent grain characters. The one strain of Winter Turf shown in table 3 has been high in yield and winter resistance and probably is the best of several developed at the Arlington Experiment Farm.

B. D. Leith and E. J. Delwiche, in Wisconsin, have bred several varieties with high yield and smut resistance by crossing on Markton. The selection (C. I. 2608) from Markton × Victory sent to Madison by the Division of Cereal Crops and Diseases in 1932 is of promise as a new smut-resistant midseason variety for Wisconsin.

At Macdonald College, Quebec, Canada, M. Summerby and E. A. Lods have developed superior varieties by hybridization in La Salle, Action, Foster, Lanark, and Mabel. At the Central Experimental Farm, Ottawa, additional improved strains have been developed. As at Macdonald College, no varieties having resistance to the smuts and rusts were used in the parentage of the new strains. However, at the Dominion Rust Laboratory, Winnipeg, two new strains with high resistance to stem rust have been evolved by hybridization of Banner and Victory, leading economic varieties, on the stem rust-resistant "Hajira strain" and Green Russian, respectively. J. N. Welsh reports that these new strains are resistant to all common physiologic forms of stem rust. At Saskatoon, Saskatchewan, under the direction of J. B. Harrington, strains have been bred that are of economic promise because of smut and stem rust resistance. Sunrise, an improved Australian variety, described in table 4, was used in several crosses because of its earliness and not because of its moderate resistance to crown rust. This resistance undoubtedly has been transmitted to some of the hybrid lines. However, as a source of basic resistance to crown rust, Victoria and Bond are far superior to Sunrise. Therefore very little emphasis can be placed on the breeding and economic value of the crown rust resistance carried by Sunrise or by the new hybrid strains at Saskatoon.

In previous paragraphs it has not been convenient to give credit to all workers who have made some contribution to the development of certain superior strains. This is especially true in the case of the many new disease-resistant lines that are being developed in the cooperative breeding program of the United States Department of Agriculture with certain States. At the Dickinson Substation, Dickinson, N. Dak., Ralph W. Smith has obtained valuable data on many new hybrid lines, the most promising being the same as those grown at some other stations, under which they are listed. Credit is also due to L. P. Reitz, Joe L. Sutherland, and M. A. Bell, of the State Agricultural Experiment Stations, the Judith Basin Branch Station, and the Northern Montana Experiment Station, located respectively at Bozeman, Moccasin, and Havre, Mont., and also to J. Foster Martin and R. W. Woodward, respectively, of the Pendleton Field Station, Pendleton, Oreg., and the Agricultural Experiment Station, Logan, Utah.

Breeders at certain State agricultural experiment stations who have cooperated informally and made contributions to the proving of these

new hybrid lines are D. W. Robertson, Fort Collins, Colo., and L. P. Reitz, Bozeman, Mont. Breeders in the South, either connected with the United States Department of Agriculture or with State agricultural experiment stations, who have played a part in determining the plant-breeding and agronomic value of the new crown rust resistant introductions from South America and Australia, and whose names have not been mentioned previously, are P. H. Kime, Raleigh (Statesville), N. C.; H. S. Garrison, Tifton, Ga.; W. P. Stokes, Gainesville, Fla.; John P. Gray, Baton Rouge, La.; and C. Roy Adair, Stuttgart, Ark.

EUROPE, ASIA, AFRICA, SOUTH AMERICA, AUSTRALIA

A summary of the information on the history, origin, breeding, value, and distribution of the improved varieties developed in Europe, Asia, Africa, South America, and Australia is given in table 4. This is similar in form to the one for North America, although less information was submitted in the questionnaires on acreage devoted to the improved varieties and those recommended for commercial production.

According to table 4, oat improvement by breeding in countries other than those of North America is confined mainly to national, State, and provincial institutions, including agricultural experiment stations and colleges and special research institutions. No questionnaires were returned from private breeders of oats abroad, although a few of the outstanding varieties developed by this group of breeders will be discussed briefly under appraisal of superior commercial varieties. Apparently there has been less coordination of the sciences of agronomy, pathology, and genetics in the breeding work than in North America. The much higher percentage of superior varieties resulting from hybridization indicates rather definitely that the genetic phase has been more strongly emphasized.

The development of new varieties with black grains is not in accord with the objectives of American breeders. Black oats are not wanted either by the farmer or by the processor in the United States and Canada. Furthermore, in Europe much less attention has been given to the breeding of disease-resistant oats. It will be noted that among the many improved varieties given in table 4, resistance to smut, rust, or other diseases is not frequently mentioned as a superior character. More attention has been given to the development of disease-resistant varieties in South America and Australia than in Europe.

Superior Varieties in Commercial Production

In direct contrast to the results presented in table 1, a much higher percentage of the improved varieties now grown commercially in Europe, Asia, Africa, South America, and Australia have originated from hybrids. The selection of Victory in Sweden is the classical example in Europe of improvement in oats by pure-line selection. Very few of the improved North American varieties have become of any commercial importance in these countries. However, varieties with outstanding special characters, such as the high stem rust resistance of the Richland and Iogold—developed in Iowa—and the high smut resistance of Markton—developed in Oregon—are now being used in these countries in breeding experiments for the transfer of

special characters to leading European types. In Australia, Fulghum, a variety distinctly American in origin, has become of some commercial importance in certain Provinces and also is being used in hybridization experiments.

Undoubtedly there are varieties—especially in the European countries—representing superior germ plasm that have persisted commercially. However, little information was obtained relative to their distribution and importance. Varieties such as Abundance in England, Potato in Scotland, Gray Winter (Winter Turf) in France, Belgium, and Germany, Beseler in Germany, Joanette in France, Red Algerian in Algeria and other north African and southern European countries, South America, and Australia, and Kherson and Tobolsk in the Union of Soviet Socialist Republics, are good examples of superior types that have continued to be of economic importance in their respective countries.

As private breeders, the Gartons of England have developed numerous varieties of oats by hybridization. Unfortunately many of these hybrids were distributed for commercial production in an unfixed or heterozygous condition. Abundance, already mentioned, obtained by crossing White August and White Swedish, has been one of their best productions. Storm King, Tartar King, Yielder, Leader, Garton Gray, Marvellous, Record, Sir Douglas Haig, Supreme, Waverly, and others, and a host of strains with numbers only such as Garton Nos. 5, 473, 585, 691, 748, 784, were developed and introduced to the trade by the Gartons. A large percentage of the Garton productions introduced into the United States have been late varieties with side or semiside panicles, large, heavy stems, large grains, and thick hulls. Consequently, as a group these varieties have been of little commercial or economic importance in the United States. However, in the cooler and more favorable climate of England, these late large-grained sorts may be preferred by growers.

It seems desirable to discuss briefly the varieties reported by the breeders of the several countries.

In Wales, E. T. Jones has concentrated on breeding for greater cold resistance and generally more satisfactory varieties for fall seeding in England and Wales. Ceirch Llwyd is an improved strain of another and distinct species, *Avena strigosa*. Of the eight varieties recommended for spring sowing, four are of Swedish breeding. William Robb, the Scottish oat breeder, has bred two excellent varieties for Scotland in Elder and Early Miller. M. Caffrey, of the Albert Agricultural College, Dublin, has developed some high-yielding, stiff-strawed varieties for Ireland. Victory also seems to be a leading commercial variety in Ireland and was used in the crosses from which were selected the improved sorts, Glasnevin Success and Glasnevin Ardri.

M. Charles Crepin and M. Schribaux have developed promising new varieties by hybridization for France. It is of interest to note that three of the improved varieties evolved at the Institut des Recherches Agronomique, Versailles, have black grains. As in England, the improved Swedish varieties, such as Victory, Star, and Eagle, are recommended. Reference also is made to the growing of Mansholt III, a Dutch variety, and to Von Lochow, a German variety. All these varieties appear to be widely adapted in Europe.

Mansholt III and Mansholt Binder, a more recently developed variety, are the products of R. J. Mansholt, of Westpolder, Netherlands, a leading oat breeder.

Many improved varieties of oats have been developed by the Swedish Seed Breeding Association at Svalof, Sweden. A few of these varieties, such as Victory and Golden Rain, are grown commercially in almost every important oat-producing country of the world. Victory, with its high yield, excellent grain quality, and great uniformity of plant characters, is one of the most valuable midseason oats ever produced. Likewise Golden Rain has been a most valuable variety, but its yellow grains have been objected to in many countries, especially where a premium is paid for white oats.

FIGURE 9.—Nils Herman Nilsson-Ehle—born in 1873 at Skurup, Sweden—is one of the world's outstanding oat breeders and cereal geneticists. His work on the mode of inheritance of morphological characters in wheat and oats has become classical. Likewise the selection and development of the famous Victory variety at Svalof by Dr. Nilsson-Ehle from the Probsteier or old Milton oat, introduced from the Baltic region of Europe, is the high water mark in oat improvement by pure-line selection in Europe.

Star and Eagle, which are of considerable promise, are newer creations of the master oat breeders at Svalof. However, it is not believed that either of these varieties will eclipse Victory in importance and value. The same may be said of Gul Naesgaard and Abed Nova, improved varieties developed by H. Vestergaard in Denmark, from whom no answer to the questionnaire was received.

The Bell (Klock), Orion, and Stormogul (Great Mogul) strains and varieties of black oats developed at Svalof apparently are of much less importance in Sweden as well as in other countries into which they have been introduced. They have been of no value in the United States.

The oat geneticists at Svalof, headed by the veteran N. H. Nilsson-Ehle (fig. 9), in addition to breeding these improved varieties, have made many valuable contributions to the advancement of knowledge on the mode of inheritance of numerous characters of the oat plant.

Unfortunately, very little information was obtained through the questionnaires sent to the plant-breeding institutions of Germany. F. von Lochow reports that his Gelbhafer (yellow oat) is adapted to all kinds of soil and to dry regions. It apparently was selected from the old commercial yellow oat of Germany.

In India, some valuable new varieties have been bred by F. J. F. Shaw and R. D. Bose, of the Imperial Department of Agriculture.

H. C. Arnold, in Southern Rhodesia, Africa, has developed two varieties resistant to stem rust and drought that are of commercial importance in that country.

In Uruguay, Alberto Boerger and Enrique Klein, the latter more recently of Argentina, have made remarkable progress in the development of oats highly resistant to crown rust. Several of these strains have been introduced into the United States, where they are being used extensively in a breeding program for the development of crown rust resistant varieties adapted to certain regions, especially where crown rust has been a limiting factor in oat production. Apparently the splendid breeding work of Boerger and Klein in developing crown rust resistance in commercial varieties has made oat production profitable in the Pla Valley of Uruguay and Argentina.

In Australia as in Sweden, much intensive breeding work with oats by hybridization is in progress. All of the varieties reported by H. Wenholz, director of plant breeding, Department of Agriculture, Sydney, New South Wales, as now being grown commercially, originated from pure-line selections or hybrids made by J. T. Pridham. Algerian—referred to as Red Algerian in the United States—Belar, Gidgee, and Mulga, in the order named, are the most important improved commercial varieties. Fulghum, an American variety, is recommended for commercial production in New South Wales. Kareela, a selection from Fulghum, is of promise. It has been introduced and tested in this country with only fair results. At Melbourne, Victoria, G. S. Gordon has developed Palestine and Dawn, improved varieties of economic importance. F. W. Hilgendorf, of Lincoln, New Zealand, has selected from College Algerians two strains, Algerians Nos. A86 and B49, which have become the leading varieties in that country.

New Superior Stocks Available

The new and superior—sometimes called elite—stocks now in process of development in countries other than those of North America are shown in table 5. As in table 2 for North America, information on the origin, breeding, superior characters, etc., is presented. A relatively smaller number of superior strains or stocks from these countries is reported, indicating that there may be less interest in oat improvement in the older countries than formerly. Breeding for resistance to disease apparently has received less attention, especially in Europe, than it has in the United States.

Nearly all the superior strains or stocks reported from these countries have resulted from hybridization and subsequent selection. This indicates that the pure-line method of breeding has been almost abandoned. The older mixed varietal stocks in cultivation for centuries have been rather completely exploited, the superior germ plasm having been isolated many decades ago. As previously stated, although more attention has been given to breeding for disease resistance in North America, more emphasis has been placed abroad—especially in Europe—on improving quality, including high percentage of meat or kernel (caryopsis), stiffer and better straw, and greater yield. New varieties of black oats are still being developed and distributed. Black oats, as previously mentioned, have become almost obsolete and are not desired either by the farmer or by the trade in North America. However, it is true that certain black-seeded varieties have shown yielding capacity in varietal experiments equaling that of the best light-colored sorts. There seems to be much less

prejudice against black oats in the oat-growing regions of Europe than in the United States and Canada.

The information in table 5 was made available through the courtesy and kindness of the various oat breeders in these countries. These strains will be discussed briefly, with some appraisal of their potential economic value and usefulness for future improvement work.

Superior strains of oats have been obtained by selecting the commercial Ceirch-du-bach variety at the Welsh Plant Breeding Station, Aberystwyth, Wales. Increased yield and greater resistance to lodging also have been obtained by selecting the commercial Ceirch Llwyd variety of *Avena strigosa*. At Cambridge, H. Hunter, a leading authority on oats, has developed Resistance, a new cross-bred white variety of much promise for growing on soils of high fertility with an abundance of moisture. Resistance also may be sown either in the autumn or in the spring.

Sonas Marvellous and Fluirse are the products of M. Caffrey, an oat breeder of Ireland. Three superior hybrid strains have been bred at Hjellum, Norway, by M. Wexselsen. F. von Lochow, a private breeder of Petkus, Germany, has developed Flamingsgold, a new variety of much promise for certain sections of Germany. He states that in 1932 there were about 110 different varieties of oats on the market in Germany but that now there are only 15 to 20, and it is hoped that the number will be reduced still further. F. von Lochow also states that the varieties named in table 4, under recommended varieties, are at present the most important cultivated oats in Germany.

At Dijon, France, Charles Crepin has developed several hybrid lines of oats that appear to be of potential promise as new varieties for his country. He is using introduced sorts from Germany and Switzerland in hybrids on the better French varieties to develop earlier oats with stiffer straw and a higher percentage of kernel. He is also breeding better winter oats for France by hybridization, but he does not give definite information on lines produced, except that Grise d'hiver (Gray Winter) is being used as one parent.

Although a black oat with low yielding power in North America, Black Mesdag has been one of the most important selections developed in France because of its high resistance to most races of the oat smuts. Black Mesdag has been used extensively by oat breeders for the transfer of smut resistance to varietal types with greater productiveness and more desirable grain characters. Reed,[7] in 1932, demonstrated that Black Mesdag is susceptible to the race of *Ustilago levis* (covered smut) that attacks Fulghum oats. This susceptibility does not mean that Black Mesdag is no longer a desirable parent for the breeding of smut-resistant northern oats. However, the much more productive yellow-seeded variety Markton is preferable to Black Mesdag for use as a smut-resistant parent in hybridization experiments.

R. D. Bose of the Imperial Department of Agriculture at Pusa, India, has developed two new smut-resistant hybrid selections which, for convenience, are listed as Hybrid X and Hybrid Y. He

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[7] REED, G. M. PLANT PATHOLOGY. Brooklyn Bot. Gard. Rec. 21: 42-46. 1932.

has used Albion (Iowa No. 103) from Iowa, Scotch Potato from Scotland, Abundance from England, and the smut resistant Pusa strains as parental material. G. S. Gordon, of the Victoria Department of Agriculture, Melbourne, Australia, has developed hybrid varieties that are of special promise for both grain and hay. Kanota, a strain of Fulghum introduced from the United States, was used as the parent of one of these new lines.

At the Department of Agriculture, Sydney, New South Wales, J. T. Pridham, under the direction of H. Wenholz, director of plant breeding, has bred many new hybrid strains of oats. Thirteen of the most promising are shown in table 5. Several are resistant to either crown or stem rust and also to smut. Others are resistant only to one or the other rust, while still others are resistant only to smut. Varieties of American, Germanic, and Swedish origin have been used as parent material in some of the hybrid oats developed by Pridham. Attention also has been given to improvement of oat varieties for grazing purposes, which is a character of considerable economic importance in New South Wales and other States of Australia.

A high percentage of the improved varieties and superior hybrid selections developed in New South Wales have been introduced and tested in the United States. So far, Bond has proved to be one of the most valuable varieties of the Australian group because of its high resistance to nearly all physiologic forms of crown rust and smut that occur in the United States, and because of its excellent straw and fair grain characters. These characters give Bond a plant breeding value perhaps not equaled by that of any other recently introduced variety. However, its late maturity and low tillering capacity are not desirable.

Most of the hybrid varieties from Australia represent intermediate types between red and common oats and are difficult to classify as to species.

Mindag selection, a reselection made from Mindag in New South Wales, is of promise because of resistance to stem rust and to the races of smut occurring in that country. Mindag is an improved variety introduced from the Agricultural Experiment Station, University Farm, St. Paul, Minn. It is listed in table 3.

Present Needs and Possibilities for the Future

THE results discussed so far show that improvement by breeding is well advanced in most of the leading oat-producing countries of the world. A summary showing the number of improved varieties actually in use and the number of new superior strains, classified according to the methods by which they were developed, is given in table 1.

TABLE 1.—*Summary of oat improvement resulting from introduction, pure-line selection, and hybridization*

Country	Improved varieties				New superior strains			
	Total listed	Introduction	Pure-line selection	Hybridization	Total listed	Introduction	Pure-line selection	Hybridization
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
North America	75	3	[1] 55	17	145	5	56	[2] 84
Europe, Asia, etc	64	0	23	[3] 41	37	2	6	[4] 29
Total	139	3	78	58	182	7	62	113
Grand total					321	10	140	171

1 Includes Kanota, which is not strictly a pure-line selection, and Swedish Select, a pure-line introduction.
2 Includes Navarro, a supposedly natural hybrid, and Bond, an introduction of known hybrid origin. Bond, therefore, is not considered in this summary as an introduction.
3 Includes one supposedly natural hybrid.
4 Includes Burdett, the origin of which is not definitely known.

Of the 75 improved varieties listed in table 2 for North America, 55 were originated as pure lines and 17 as hybrids, and 3 are classed as introductions. In other words, 73 percent of the improved varieties now grown commercially in the United States and Canada resulted from pure-line selection made from superior variable stocks or populations introduced at one time or another from the older oat-producing countries, particularly those of Europe.

Sixty-four improved varieties were reported from countries other than those of North America. Of this number, 23, or about 36 percent, are classed as pure lines and 41 as hybrids, there being no varieties considered as introductions. These figures show that hybridization as a method of improvement in these countries has been used more extensively than in the United States and Canada. By reference to table 4, it will be seen that many varieties now cultivated in the British Isles and Sweden are of hybrid origin.

The 145 superior strains or stocks listed in table 3 for the United States and Canada are of much interest for two reasons: (1) The relatively large number of strains now available indicates that there has been an increased interest in oat improvement during recent decades, and (2) there is a rapid trend toward hybridization as a method of improvement. Table 1 shows that of the 145 strains, 84, or about 58 percent, resulted from hybridization followed by selection; 56, or nearly 39 percent, originated from pure-line selections; and 5 are considered as introductions. It must be pointed out that while many introductions have been made and are being made, especially in the United States, relatively few ever attain great commercial importance. However, some of those that do not become important may be considered as representing superior germ plasm because of special characters of plant-breeding value.

Of the 37 superior lines reported from abroad (table 5), 29, or 78 percent, originated from hybrids, 6 originated from pure-line selections, and 2 fall in the category of introductions. These figures show definitely that pure-line breeding has been almost completely replaced by hybridization in these countries.

The demand for superior stocks resistant to diseases, such as the rusts and smuts, has greatly stimulated interest in hybridizing for the combining of disease-resistant genes with those for high yield, stiff straw, thin hull, and other desirable characters. Up-to-date breeding programs also emphasize the development of varieties for special

purposes, such as hay, grazing, green feed, and manufacturing. Breeding for greater winter resistance in fall-sown oats offers an attractive field since the development of freezing equipment for artificially testing cold resistance. However, there is great need for the introduction or discovery of stocks with greater basic cold resistance than any now available to the hybridist. Another mode of attack is to transfer hardiness by interspecific crossing from closely allied species of the genus *Avena* belonging to groups other than *Euavena*.

A RESERVOIR *of superior germ plasm in the form of elite stocks is being accumulated in North America through the processes of introduction and breeding. The demand for superior stocks resistant to certain destructive diseases, such as the rusts and smuts, has greatly stimulated interest in hybridizing for the combining of genes for disease resistance with those for high yield, stiff straw, thin hull, and other desirable characters. Up-to-date breeding programs also emphasize the development of varieties for special purposes, such as hay, grazing, green feed, and manufacturing. Breeding for greater winter resistance in fall-sown oats offers an attractive field since the development of freezing equipment for artificially testing cold resistance. With 300 improved varieties and superior strains available for hybridization in all countries, the outlook for further advances is exceedingly bright. Never before has there been such a wealth of superior germ plasm awaiting the genius, industry, and perseverence of the hybridist for exploitation.*

In conclusion, it would appear that, with more than 300 improved varieties and superior (elite) strains available for hybridization in all countries, the outlook for further advances is exceedingly bright. Never before has there been such a wealth of superior germ plasm awaiting the genius, industry, and perseverance of the oat hybridist for exploitation.

A list of workers engaged in the improvement of oats in research institutions in North America and abroad is given in the appendix (p. 409).

Some Notes on the Genetics and Cytology of the Oat Plant

SPECIES AND CHROMOSOME NUMBER

INVESTIGATIONS conducted by various cytologists in recent years have established three groups of the species of *Avena* classified according to chromosome numbers.

Group 1 (Seven Haploid Chromosomes)

Avena brevis Roth (short oat), *A. wiestii* Steudel (desert oat), *A. strigosa* Schreb. (sand oat), and *A. nudibrevis* Vav. [*A. nuda biaristata* (small-seeded naked oat)].

Group 2 (14 Haploid Chromosomes)

Avena barbata Pott (slender oat), *A. abyssinica* Hochst. (Abyssinian oat).

Group 3 (21 Haploid Chromosomes)

Avena fatua L. (common wild oat), *A. sativa* L., including *A. orientalis* Schreb. (common white or northern oat), *A. nuda* L. (large-seeded naked or hull-less oat), *A. sterilis* L., including *A. ludoviciana* Dur. (wild red or animated oat), and *A. byzantina*, C. Koch, including *A. sterilis algeriensis* Trabut (cultivated red oat).

Formerly it was believed that owing to the difference in chromosome numbers hybrids between the species or groups 1 and 2, groups 1 and 3, and groups 2 and 3 were not possible. However, Kihara and Nishiyama[8] have reported an entire series of crosses involving species in all three chromosome groups and have studied them cytologically. The discovery that all oat species and subspecies are found in some one of the three caryological groups has been of great value in advancing knowledge on their origin and relationships. On the basis of cytological characteristics, it appears that external morphological characters alone may not show the exact degree of relationship of *Avena* species.

WILD OATS

The common wild oat, previously noted as the progenitor of *Avena sativa*, is a noxious weed in many sections of the world. It is one of the most difficult to eradicate because of the ability of the seeds to lie dormant in a dry soil for years, and then to germinate and grow when moisture and temperature conditions become favorable. The wild oat is most troublesome as a weed in North America in the hard spring wheat area of Minnesota, the Dakotas, and Montana, and in the wheat areas of western Canada. It can be differentiated from culti-

[8] KIHARA, H., and NISHIYAMA, I. THE GENETICS AND CYTOLOGY OF CERTAIN CEREALS, III. DIFFERENT COMPATIBILITY IN RECIPROCAL CROSSES OF AVENA WITH SPECIAL REFERENCE TO TETRAPLOID HYBRIDS BETWEEN HEXAPLOID AND DIPLOID SPECIES. Japan. Jour. Bot. 6: [245]-305, illus. 1932.

vated oats in the field by the taller and more vigorous plant and by the strongly twisted, geniculate (sharply bent) awns. It can also be differentiated by the pronounced "sucker-mouth" base and usually by the hairiness of the lemma. The dry awns are stiff and twisted, and when moistened they become pliable and untwist. By this means the seeds are able to bore into the soil. Many carloads of so-called "feed oats", representing about 80 percent of wild oats screened from hard spring wheat in the process of milling, are sold for feeding purposes each year in the United States and abroad. Owing to a slightly higher percentage of hull or fiber, these wild oats have about 90 percent of the feeding value of cultivated oats.

Only the common wild oat is found as a noxious weed in North America. The wild red oat is found growing wild in some sections of the world, but it apparently has not become of much importance as a weed, at least in this country. Forms of *Avena sterilis* are found growing on the campus of the University of California, where they apparently were sown some years ago by a member of the scientific staff of that institution. These wild forms apparently have not spread widely from this original sowing, and therefore have not become menacing as weeds in the United States.

Avena barbata, a wild oat form found in the Pacific Coast States, is an important range grass in California. It differs primarily from *A. fatua* in having a decidedly more slender culm and longer and more slender grain. In certain sections of the Old World, *A. strigosa* also is an important hay and pasture grass.

FATUOIDS

Fatuoids or false wild oats have been observed in cultivated oat varieties for many years both in North America and abroad. The sudden appearance of these forms—which resemble the common wild oat, *Avena fatua*—in standard varieties and elite stocks arising from pure lines or hybrids, has been of considerable scientific and genetic interest, as well as of some agricultural importance. Fatuoids have been found in nearly all varietal types of the common oat and also in the cultivated red oat, at least in the varieties Burt and Fulghum (Kanota).

Their frequency in Fulghum has been greater than in any other variety, regardless of group. As a matter of fact, it was this great frequency in Fulghum that stimulated renewed interest in their origin about 15 years ago. So far as is known, no fatuoids have been found in the Red Rustproof variety and its strains. The opinion has been generally held that fatuoids do not occur frequently enough to be of much agricultural importance, especially in the varieties of common oats. Most farmers do not object to these wildlike forms in Fulghum, yet the development of strains free from fatuoids would be very desirable from the standpoint of oat production. So far, it has not been possible to isolate pure lines of Fulghum that do not throw fatuoids. Several varieties of oats have been produced by Zhegalov in

Russia which appear to be nonfatuoid-producing. By crossing on these varieties, it is possible that oats might be developed that would not carry the factors for the fatuoid complex.

Fatuoid forms usually show many characters common to the variety in which they are found. For example, fatuoids occurring in black oats are black like the parent; in gray oats they are gray, and so on. However, all such forms are similar to each other in many general characters, regardless of the variety in which they occur. The more prominent characters of the fatuoid floret are a prominent basal cavity; so-called sucker mouth; dense and often very long hairs or bristles on the base of the lemma, as well as on the rachilla segment; and a long, twisted, and geniculate or sharply bent awn on all florets of the spikelet. At maturity, fatuoids shatter quickly, as do common wild oats.

Difficulty has arisen in the certification of oats in areas where *Avena fatua* is a noxious weed, because it is confused with the occasional fatuoid that occurs in the cultivated variety. Typical fatuoids from a cultivated common oat are shown in figure 10.

Up to about 10 years ago the opinion prevailed that fatuoids originate through (1) natural crossing of *Avena sativa* and *A. fatua* or (2) by loss mutation from *A. sativa*. Most of the evidence supported the latter theory. The heterozygous form, which is intermediate between the normal (cultivated) and the fully developed fatuoid, appears first. These intermediate forms segregate in the next generation into normals, heterozygotes, and fatuoids in a ratio approximating 1:2 :1.

On the basis of cytological investigations, Huskins [9] has advanced the theory that these fatuoids arise from irregularities in chromosome number and formation. This phenomenon is frequently referred to as chromosome aberration, meaning that the fatuoids do not carry a complete complement of chromosomes such as are found in the cultivated varieties of *Avena sativa* and *A. byzantina*. Huskins and other investigators of the fatuoid problem have now grouped the fatuoids into several classes, depending on the height, vigor, fatuoid characters, etc., of the aberrant. The work of Huskins has demonstrated that the fatuoid complex is similar cytologically and genetically to the so-called speltoid complex in wheat.

In several instances wild forms resembling the species *Avena sterilis*, and called steriloids, have been found in cultivated varieties of *A. sativa*. These, however, have never been found in sufficient numbers to warrant the interest that has been manifested in the origin and nature of fatuoids. To one with imagination, the occurrence of fatuoids might be considered a provision of nature to return cultivated oats to wild forms, thus making them self-propagating in case, through some disaster, the cultivated forms were no longer in the hands of human beings.

[9] HUSKINS, C. L. GENETICAL AND CYTOLOGICAL STUDIES OF THE ORIGIN OF FALSE WILD OATS. Sci. Agr. 6: 303-313, illus. 1926

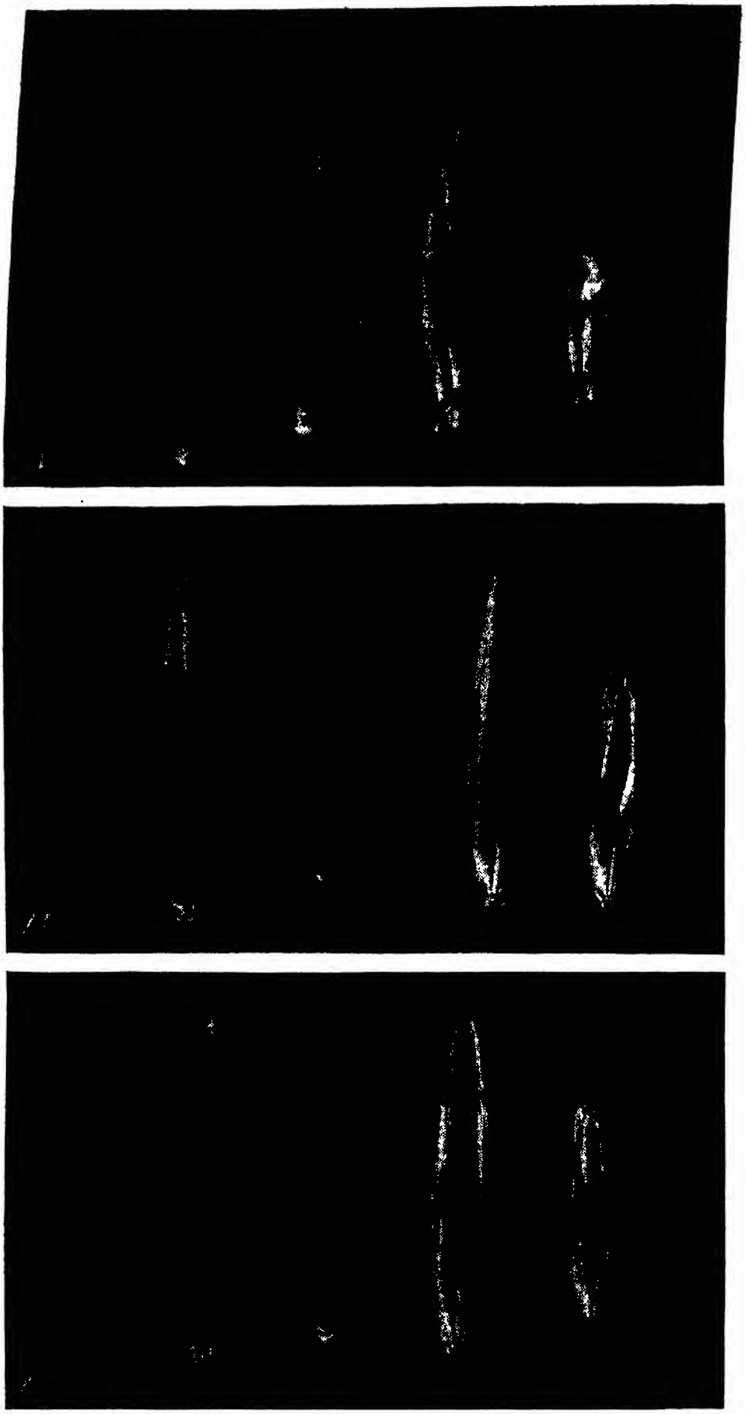

FIGURE 10.—Typical florets of fatuoids from Iogold oats: *A*, fatuoid; *B*, intermediate form; *C*, normal.

Appendix

INHERITANCE OF CHARACTERS IN OATS

Monogenic

The 3:1 type

(1) Black grain—nonblack grain.
(2) Gray grain—white grain.
(3) Yellow grain—white grain.
(4) Red grain—nonred (yellow, white) grain.
(5) Spreading panicle—side panicle.
(6) Long-haired glumes—glabrous glumes.
(7) Short-haired glumes—glabrous glumes.
(8) Nonstrongly awned types—strongly awned types (data much complicated).
(9) Presence of ligules—absence of ligules.
(10) Pubescent back of the lower grain—glabrous back of the lower grain.
(11) Glabrous base of the upper grain—pubescent base of the upper grain.
(12) Long hairs at the base of the lower grain—short hairs at the base of the lower grain.
(13) Short hairs at the base of the lower grain—no hairs at the base of the lower grain.
(14) Glabrous type of grain (or nearly glabrous)—medium-haired Burt type of grain.
(15) Nonarticulated type of the upper grain—articulated (*fatua*) type of the upper grain.
(16) Glabrous rachilla—pubescent rachilla.
(17) Normal type—dwarf type.
(18) Dwarf type—normal type.
(19) Few hairs or glabrous type of rachilla—pubescent type (*sativa*) rachilla.
(20) Resistance to crown rust—susceptibility to crown rust.
(21) Resistance to stem rust—susceptibility to stem rust.
(22) Susceptibility to stem rust—resistance to stem rust.
(23) Resistance to loose smut—susceptibility to loose smut.
(24) Resistance to covered smut—susceptibility to covered smut.

The 1:2:1 type

(25) Deep-gray grain—light-gray grain.
(26) Waxy lemma—nonwaxy lemma.
(27) Awnless type—strong-awned type.
(28) Awnless type—weak-awned type.
(29) Normal type—fatuoid type.
(30) Covered grain—hull-less grain.
(31) Glabrous base of the lower grain—pubescent base of the lower grain.
(32) Nonarticulated base of the lower grain—articulated (*Avena fatua* and Burt) base of the lower grain.

Digenic

The 15:1 type

(33) Black grain—nonblack grain.
(34) Yellow grain—white grain.
(35) Spreading panicle—side panicle.
(36) Pubescent glumes—glabrous glumes.
(37) Pubescent back of the lower grain—glabrous back of the lower grain.
(38) Pubescent base of the lower grain—glabrous base of the lower grain.
(39) Presence of ligules—absence of ligules.
(40) Resistance to loose smut—susceptibility to loose smut (data incomplete).
(41) Early heading—late heading (data incomplete).
(42) Many aborted pollen grains—few aborted pollen grains (data incomplete)

The 13:3 type

(43) Glabrous back of the upper grain—pubescent back of the upper grain.
(44) Susceptibility to stem rust—resistance to stem rust.

Trigenic

The 63:1 type

(45) Long grain—short grain (data incomplete).
(46) Presence of ligules—absence of ligules.
(47) Green seedlings—"lutescens" seedlings.
(48) Resistance to covered smut—susceptibility to covered smut (no data).
(49) Resistance to loose smut—susceptibility to loose smut (data incomplete).
(50) Early ripening—late ripening (the homozygous early plants appearing in 11:64).

The other types

(51) Spreading panicle—side panicle (45:19).
(52) Pubescent back of the lower grain—glabrous back of the lower grain (57:7).

Tetragenic

The 255:1 type

(53) Presence of ligules—absence of ligules.

Multigenic

(54) Height of plants.
(55) Breadth of leaves.
(56) Number of florets per spikelet.
(57) Number of culms.
(58) Length of rachilla.
(59) Heading period.
(60) Resistance to stem rust.

TABLE 2.—*Historical summary of the development of improved varieties of oats in the United States and Canada primarily by breeding through the application of pure-line selection to superior old mixed stocks grown in North America for many years or to superior indigenous and comparatively recently introduced stocks, mainly from Europe, or by hybridization (and subsequent selection) of the superior strains and varieties arising from these two groups of plant material*

Country, State, or Province, developing institution, and variety	Registration no.[1]	Year introduced, selected, or hybridized	Name of breeder	Superior characters	Breeding method used—mass or pure-line selection, or hybridization	Parent material	When distributed to farmers	Percentage of present acreage[2]	Recommended varieties by States or Provinces
United States									
Alabama:									
Agricultural Experiment Station, Auburn:									
Red Rustproof No. 740.		1910	J. F. Duggar	Cold resistance, high yield, "late ruster."	Pure-line selection.	Red Rustproof	1918	50	Red Rustproof; Fulghum, Norton.
Fulghum No. 321		1910	do	Early maturity, moderate cold resistance, high yield.	do	Fulghum	1918	25	Do.
Colorado:									
Agricultural Experiment Station, Fort Collins:									
Colorado No. 37	33	1900	A. H. Danielson, Alvin Kezer, and D. W. Robertson.	Stiff straw, high yield, awnless.	do	Unnamed commercial variety.	1922	75	Colorado No. 37 (irrigated); Kanota, Brunker (dry land).
United States Dry-Land Field Station, Akron:									
Brunker	73	1919	F. A. Coffman and T. R. Stanton.	High yield, uniformity of plant characters, drought resistance, smut resistance.	do	Burt	1930	3+	Do.
Georgia:									
J. A. Fulghum (private farmer), Warrenton: Fulghum.	[3] 3	[4] 1900	J. A. Fulghum	Early maturity, high yield, high test weight.	do	Red Rustproof	[4] 1908	About 5,000,000 acres annually of all strains in U. S.	Fulghum, Red Rustproof.
Idaho:									
Aberdeen Substation, Aberdeen (in cooperation with U. S. Department of Agriculture): Idamine.	57	1915	C. W. Warburton, L. C. Aicher, H. W. Hulbert, and A. E. McClymonds.	Stiff straw, excellent grain color, high yield.	do	Silvermine (Funk)	1924	15–	Idamine, Markton; Victory.

See footnotes at end of table.

Table 2.—*Historical summary of the development of improved varieties of oats in the United States and Canada primarily by breeding through the application of pure-line selection to superior old mixed stocks grown in North America for many years or to superior indigenous and comparatively recently introduced stocks, mainly from Europe, or by hybridization (and subsequent selection) of the superior strains and varieties arising from these two groups of plant material*—Continued

Country, State, or Province, developing institution, and variety	Registration no.[1]	Year introduced, selected, or hybridized	Name of breeder	Superior characters	Breeding method used—mass or pure-line selection, or hybridization	Parent material	When distributed to farmers	Percentage of present acreage [2]	Recommended varieties by States or Provinces
United States—Con.									
Iowa:									
Agricultural Experiment Station, Ames (in cooperation with U. S. Department of Agriculture):									
Richland (Iowa No. 105).	44	1906	L. C. Burnett and C. W. Warburton.	Early maturity, short, stiff straw, high yield, high resistance to stem rust.	Pure-line selection.	Kherson	1914	20+	
Iogold	72	1906	do	Early maturity, stiff straw, high yield, high resistance to stem rust.	do	do	1926	20+	
Albion (Iowa No. 103).	46	1906	do	White grain, early maturity.	do	do	1913	15	Richland, Iogold; Iowar.
Iowar	48	1910	do	High yield, white grain	do	do	1919	10+	
Iogren	51	1910	do	High yield, midseason maturity.	do	Green Russian	1922	5	
Iowa No. 444		1907	do	High yield, moderate resistance to stem rust, white grain.	do	"Rustless" (from Iowa).	1929	1+	
Kansas:									
Agricultural Experiment Station, Manhattan (in cooperation with U. S. Department of Agriculture) Kanota.	66	1916	S. C. Salmon, R. P. Bledsoe, K. S. Quisenberry, and J. H. Parker.	Early maturity, high yield, high test weight.	Mass selection	Nicholson Extra Early Red Rustproof (a commercial strain of Fulghum).	1919	75+	Kanota.
Maine:									
Agricultural Experiment Station, Orono: Maine No. 340.		1910	F. M. Surface and Jacob Zinn.	High yield, stiff straw	Pure-line selection.	Irish Victor	1916	75	Gopher, Maine No. 340.
Michigan:									
Agricultural Experiment Station, East Lansing:									

Wolverine	71	1911	F. A. Spragg	Midseason maturity, high yield.	do	Unknown, Silvermine type.	1917	75−	Markton, Victory, Wolverine, and Worthy.
Worthy	70	1906	do	Stiff straw, adapted to heavy soil.	do	Improved American.	1911	7−	Do.
Minnesota: Agricultural Experiment Station, St. Paul:									
Gopher	47	1917	H. K. Hayes and Lee Alexander.	Early maturity, stiff straw, high yield, white grain.	do	Sixty-Day	1923	30+	
Minrus		1918	H. K. Hayes and R. J. Garber.	Stem-rust resistance, high yield (on both mineral and peat soils).	Hybridization	Minota × White Tartar (White Russian).	1931	15+	Gopher, Minrus, Anthony, Iogold, and Rusota.
Anthony	75	1918	do	Stem-rust resistance, high yield.	do	White Tartar (White Russian) × Victory.	1929	15	Do.
Minota	59	1906	C. P. Bull, H. K. Hayes, and A. C. Arny.	High yield, short straw, midseason maturity.	Pure-line selection.	Unnamed commercial variety.	1919	2−	
Missouri: Agricultural Experiment Station, Columbia: Columbia.	78	1920	L. J. Stadler	Early maturity, high yield, few awns, adapted to late seeding.	do	Fulghum	1930	30+	Columbia, Fulghum.
Nebraska: Agricultural Experiment Station, Lincoln:									
Kherson	[3] 22	1896	F. W. Taylor	Early maturity, high yield.		Introduction from Russia.	1901	30−	Nebraska No. 21, Kherson, Iogold.
Nebraska No. 21		1909	E. G. Montgomery and T. A. Kiesselbach.	Early maturity, high yield, white grain.	Pure-line selection.	Kherson	1917	50−	Do.
New York: Cornell University Agricultural Experiment Station, Ithaca (in cooperation with U. S. Department of Agriculture):									
Cornellian	50	1912	H. H. Love	High yield, low hull percentage, very few awns.	do	Canada Cluster	1920	About 20	Cornellian, Ithacan, Upright, Keystone, Patterson, and Lenroc.
Ithacan	58	1914	H. H. Love and W. T. Craig.	High yield	do	National (Silvermine type).	1922	About 10	Do.
Upright	61	1914	do	High yield, stiff straw	do	American Beauty	1918	do	Do.
Lenroc	80	1918	do	High yield, white grain.	Hybridization	Great American × Cornellian.	1936		Do.

See footnotes at end of table.

TABLE 2.—*Historical summary of the development of improved varieties of oats in the United States and Canada primarily by breeding through the application of pure-line selection to superior old mixed stocks grown in North America for many years or to superior indigenous and comparatively recently introduced stocks, mainly from Europe, or by hybridization (and subsequent selection) of the superior strains and varieties arising from these two groups of plant material*—Continued

Country, State, or Province, developing institution, and variety	Registration no.[1]	Year introduced, selected, or hybridized	Name of breeder	Superior characters	Breeding method used—mass or pure-line selection, or hybridization	Parent material	When distributed to farmers	Percentage of present acreage [2]	Recommended varieties by States or Provinces
United States—Con.									
North Dakota:									
Agricultural Experiment Station, Fargo:									
Rainbow	74	1925	T. E. Stoa	High yield, high resistance to stem and moderate resistance to crown rust.	Pure-line selection.	Green Russian	1930	10+	Gopher, Rainbow, Anthony, Iogold, Rusota, and Victory.
Rusota	81	1925	do	High yield, moderate resistance to stem rust, white grain.	do	do	1935		Do.
Ohio:									
Agricultural Experiment Station, Wooster:									
Wayne	77	1909	C. G. Williams and A.D. Shelby.	Stiff straw, high yield	Hybridization	Unknown	1930	20+	Wayne, Miami, Franklin, and Fulghum (Kanota).
Miami	76	1900	C. G. Williams	High yield and quality	Pure-line selection.	Improved American.	1912	20	Do.
Franklin	79	1922	H. L. Borst	High yield, stiff straw	do	Fulghum	1931	10−	Do.
Oregon:									
Agricultural Experiment Station, Corvallis (in cooperation with U. S. Department of Agriculture): Support.	83	1926[5]	H. A. Schoth, E. N. Bressman, and C. C. Ruth.	High yield, stiff straw, earlier than Winter Turf, adapted for growing with annual viny legumes.	Hybridization	Unknown, record of parent varieties lost.	1931	1+	
Sherman County branch station, Moro (in cooperation with U. S. Department of Agriculture): Markton.	52	1911	D. E. Stephens, H. J. C. Umberger, E. F. Gaines, and M. A. Carleton.	High resistance to smut, high yield, thin hull.	Pure-line selection.	C. I. No. 357 (an unnamed introduction).	1922	50+	Markton, Victory, Schoolmam, Winter Turf (Gray Winter), Support, Three Grain, and Shadeland Eclipse.

N. C. Nairn, Amity (private breeder): Shadeland Eclipse.		1907[4]	N. C. Nairn	High yield, large grain	do	Shadeland Challenge.	1912[4]	6	Do.
nsylvania: Agricultural Experiment Station, State College:									
Patterson	69	1911	C. F. Noll	High yield, thin hull	do	Japan	1921	40+	Patterson, Keystone, Cornellian.
Keystone	68	1911	do	do	do	do	1921	10	Do.
ith Carolina: Coker's Pedigreed Seed Co., Hartsville.									
Coker Appler No. 3		1910	D. R. Coker and G. J. Wilds.	Early maturity, high yield.	do	Red Rustproof (Appler).	1925	15	Coker Fulghum No. 4; Coker Norton No. 3; Coker No. 33-50; Coker No. 32-1; Coker No. 33-47; Coker No. 33-19, Marett Fulghum No. 34-4.
Coker Fulghum No. 4.		1930	G. J. Wilds	High yield, uniformity of plant characters.	do	Fulghum	1932	50	Do.
Coker Norton No. 3		1919	J. B. Norton	Cold resistance, stiff straw, high yield.	Hybridization	Gray side selection from Red Rustproof × Fulghum.	1927	10	Do.
Coker No. 33-50		1924	G. J. Wilds	Smut resistance, high yield, stiff straw.	do	Fulghum × Navarro.	1933	1	Do.
Coker No. 32-1		1925	do	Smut and cold resistance, high yield.	do	Norton No. 2 × Navarro.	1934	1	Do.
Coker No. 33-47		1925	do	Smut and cold resistance, tall, stiff straw, heavy tillering.	do	Norton No. 20-93 × Navarro.	1935		Do.
Coker Fulgrain No. 33-19.		1925	do	Smut and cold resistance, very large heavy grain, earlier than Fulghum.	do	do	1936		Do.
Marett Farm and Seed Co., Westminster:									
Marett Fulghum No. 34-4.		1929	W. T. McClure	High yield, stiff straw, moderate resistance to cold.	Pure-line selection.	Marett Fulghum No. 34.	1934		Do.
Marett Winter Resistant No. 1.		1929	do	High yield, stiff straw, cold resistance.	do	Norton (Coker)	1934		Do.
ith Dakota: Highmore Substation, Highmore: Cole		1905	J. S. Cole	Earlier than Sixty-Day, high yield, white grain.	do	Kherson	1907	10	Rhland, Cole, Gopher, Iogold, Rainbow.

Table 2.—*Historical summary of the development of improved varieties of oats in the United States and Canada primarily by breeding through the application of pure-line section to superior old mixed stocks grown in North America for many years or to superior indigenous and comparatively recently introduced stocks, mainly from Europe, or by hybridization (and subsequent selection) of the superior strains and varieties arising from these two groups of plant material*—Continued

Country, State, or Province, developing institution, and variety	Registration no.[1]	Year introduced, selected, or hybridized	Name of breeder	Superior characters	Breeding method used—mass or pure-line selection, or hybridization	Parent material	When distributed to farmers	Percentage of present acreage [2]	Recommended varieties by States or Provinces
United States—Con.									
Texas:									
Agricultural Experiment Station, Substation No. 6, Denton:									
Nortex	67	1920	A. H. Leidigh, C. H. McDowell, and P. B. Dunkle.	Early maturity, stiff straw, high yield, "late ruster."	Pure-line selection.	Red Rustproof	1926	50+	
Frazier	65	1920	do	Early maturity	do	do	1926	5−	Nortex, Ferguson No. 922, Frazier.
Ferguson Seed Farms (formerly at Sherman, now at Howe):									
Ferguson No. 71		1902	A. M. Ferguson	Cold resistance, high yield, uniformity of plant characters, "late ruster."	do	Texas Red Rustproof.	1912	10−	Do.
Ferguson No. 922		1918	do	do	do	Ferguson No. 71	1923	25+	
Vermont:									
University of Vermont, Burlington: Pringle Progress		1870	C. G. Pringle	High yield, white grain, early maturity.	Hybridization	Excelsior × Chinese Hull-less.	1875	Very small	Ithacan, Cornellian, Upright.
Virginia:									
Agricultural Experiment Station, Blacksburg: Tech.	63	1906	T. B. Hutcheson	High yield and cold resistance.	Pure-line selection.	Culberson	1920	Very small	Winter Turf (Gray Winter), Lee, Tech, and Fulghum.
U. S. Department of Agriculture, Arlington Experiment Farm, Rosslyn:									
Lee	64	1916	T. R. Stanton and J. W. Taylor.	High yield and quality, cold resistance, stiff straw.	Hybridization	Winter Turf × Aurora.	1925	5+	Do.

Winter Turf (C. I. 3296).		1908	C. W. Warburton and T. R. Stanton.	High yield, winter resistance, resistance to lodging.	Pure-line selection.	Winter Turf (from Burns, Tenn.).	1912	5–	
sconsin:									
Agricultural Experiment Station, Madison:									
State Pride	45	1906	B. D. Leith	High yield, thin hull, early maturity.	do	Kherson	1912	35+	**State Pride, Forward, Wisconsin Wonder, Spooner, White Cross, Wisconsin No. 5.**
Wisconsin Wonder	62	1901	R. A. Moore and A. L. Stone.	Stiff straw, high yield	do	Silvermine	1909	10	**Do.**
Wisconsin No. 5		1899	do	High yield	do	Swedish Select	1909	3	**Do.**
White Cross	49	1911	B. D. Leith	Early maturity, white grain.	Hybridization	Sixty-Day × Big Four.	1918	3	**Do.**
Ashland Branch Station, Ashland: Forward.	56	1912	E. J. Delwiche	High yield, stiff straw	Pure-line selection.	Silvermine	1920	15+	
Spooner Branch Station, Spooner: Spooner.	82	1913	do	High yield, adapted to sandy soils.	do	Wisconsin No. 8 (Silvermine type).	1925	7+	
shington, D. C.:									
Department of Agriculture, Bureau of Plant Industry, Division of Cereal Crops and Diseases:									
Swedish Select	3 31	1899	M. A. Carleton	High yield, stiff straw	Pure-line selection (in Russia).	(Introduction from Russia, a selection from Ligowo.)	1901 4	Decreasing	
Sixty-Day	3 22	1901	M. A. Carleton and S. de Mrozinski.	High yield, thin hull, drought resistance.	do	(Introduction from Russia.)	1905 4	do	
Canada									
tario:									
Department of Field Husbandry, Ontario Agricultural College, Guelph:									
O. A. C. No. 72		1903	C. A. Zavitz, C. R. Klinck, W. J. Squirrel, and A. W. Mason.	High yield, stiff straw	Pure-line selection.	Siberian (from Russia).	1911		**Banner, Victory, Alaska, O. A. C. No. 72, O. A. C. No. 144, O. A. C. No. 3, Abundance, Golden Rain.**

TABLE 2.—Historical summary of the development of improved varieties of oats in the United States and Canada primarily by breeding through the application of pure-line selection to superior old mixed stocks grown in North America for many years or to superior indigenous and comparatively recently introduced stocks, mainly from Europe, or by hybridization (and subsequent selection) of the superior strains and varieties arising from these two groups of plant material—Continued

Country, State, or Province, developing institution, and variety	Registration no.[1]	Year introduced, selected, or hybridized	Name of breeder	Superior characters	Breeding method used—mass or pure-line selection, or hybridization	Parent material	When distributed to farmers	Percentage of present acreage[2]	Recommended varieties by States or Provinces
Canada—Continued									
Ontario—Continued.									
Department of Field Husbandry—Con.									
O. A. C. No. 3		1904	C. A. Zavitz, C. R. Klinck, W. J. Squirrel, and A. W. Mason.	Early maturity, white grain, few awns, thin hull, high yield.	Pure-line selection.	Daubeney	1913		Banner, Victory, Alaska, etc.
O. A. C. No. 144		1913	C. R. Klinck, C. A. Zavitz, W. J. Squirrel, and A. W. Mason.	High yield, large stiff straw, excellent grain quality.	do	O. A. C. No. 72	1923		
O. A. C. No. 157		1911	C. R. Klinck, C. A. Zavitz, W. J. Squirrel, and A. W. Mason.	Early maturity, thin hull, high percentage of kernel.	do	Alaska	1930		
Central Experimental Farm, Ottawa:									
Banner (Ottawa No. 049).		1905	C. E. Saunders	High yield, wide adaptation.	do	Banner (commercial).	1910	25 (in Canada)	Banner (Ottawa No. 049) and Victory for eastern and western Canada; Alaska for eastern Canada; Cartier for Quebec; Gopher for western Canada; O. A. C. No. 72 for Ontario; and Anthony for stem-rust area.
Legacy (Ottawa No. 678).		1906	do	Early maturity, high yield.	Hybridization	Banner (Ottawa No. 049) × Eighty-Day.	1930	1 to 2	Do.

Laurel (Hull-less, Ottawa No. 474).		1906	do	High yield, stiff straw	do	Chinese Hull-less × Banner.	1930	Less than 1	Do.
Liberty (Hull-less, Ottawa No. 480).		1906	do	do	do	Chinese Hull-less × Swedish Select.	1914		Do.
Quebec:									
Macdonald College (McGill University), Macdonald College:									
Banner No. M. C. 44 (C. A. N. No. 10).		1907	L. S. Klinck, G. H. Cutler, and R. Summerby.	High yield	Pure-line selection.	Banner (Dery strain).	1921	Grown almost exclusively in sections in which midseason oats are best adapted.	Banner M. C. No. 44; Banner (Ottawa) No. 049), Victory, Legacy, Cartier.
Cartier (C. A. N. No. 133).		1913	R. Summerby and E. A. Lods.	High yield, low percentage of hull, early maturity.	Hybridization	Alaska × Early Triumph M. C. No. 108.	1931	Rapidly replacing other early varieties.	Do.
Alaska (C. A. N. No. 458).		1907	L. S. Klinck and R. Summerby.	Early maturity	Introduction (by O. A. C.).	Unknown	1918	Grown in northern and southwestern Quebec and in eastern Ontario.	Do.
Saskatchewan:									
Department of Field Husbandry, University of Saskatchewan, Saskatoon: Banner (Sask. No. 144).		1918		High yield, plump grain	Pure-line selection.	Banner (Saskatchewan No. 99).	1921	10	Banner, Victory, Gopher.

[1] Registered as a variety of merit by the American Society of Agronomy and the Bureau of Plant Industry, cooperating.
[2] Approximate estimates only; + sign indicates acreage probably increasing; − sign indicates acreage probably decreasing; otherwise stabilized or status of variety not known.
[3] Registered as a standard variety by the American Society of Agronomy and the Bureau of Plant Industry, cooperating.
[4] About.
[5] Year last selected.

Table 3.—*Summary of the development of new superior strains and stocks of oats in the United States and Canada by breeding through the application of pure-line selection to adapted old, mixed varieties grown in these countries for varying periods of years or to adapted introduced stocks, mainly from Europe, or by hybridization (and subsequent selection) of varieties, including many of the improved ones shown in tables 2 and 4*

Country, State or Province, developing institution, and strain	Year selected or hybridized	Name of breeder	Superior characters	Breeding method used	Parent material
United States					
Alabama:					
Agricultural Experiment Station, Auburn:					
Red Rustproof No. 43a	1930	H. B. Tisdale	Cold resistance, high yield, stiff straw, "late ruster."	Pure-line selection	Red Rustproof.
Fulghum No. 6a	1930	do	Early maturity, stiff straw, cold resistance.	do	Fulghum.
Arkansas:					
Agricultural Experiment Station, Fayetteville:					
Culberson selection No. 5	1917	C. K. McClelland and L. W. Osborn.	Cold resistance, high yield	do	Culberson.
Arkansas No. 1	1917	do	do	do	Do.
Arkansas No. 12	1917	do	do	do	Do.
Colorado:					
United States Field Station, Akron:					
Trojan (C. I. 2491)	1921	F. A. Coffman, K. S. Quisenberry, and J. H. Parker.	Very early maturity, white grain, drought resistance, stiff straw, smut resistance.	do	Burt.
Burt selection No. 5211-97 E (C. I. 3225).	1921	do	Early maturity, tall straw, high yield	do	Do.
Burt selection No. 6094-73 E (C. I. 3226).	1921	do	High grain quality	do	Do.
Kherson selection No. 459-14-1 (C. I. 3010).	1922	F. A. Coffman and T. R. Stanton.	High yield, tall straw, early maturity	do	Kherson.
Kherson selection No. 459-6-4 (C. I. 3163).	1922	do	High yield, early maturity	do	Do.
Edkin (C. I. 2330)	1922	do	High resistance to stem rust, high yield.	do	Do.
Georgia:					
Agricultural Experiment Station, Experiment:					
Georgia No. P233	1922	R. P. Bledsoe	High yield	do	Red Rustproof.
Georgia No. P821	1928	do	do	do	Do.
Georgia No. H209-4-11-16 (C. I. 3178).	1925	do	High yield, winter and moderate smut resistance.	Hybridization	Markton (C. I. 2053) × Red Rustproof (Georgia No. P. 254).

Georgia No. H209-4-11-18 (C. I. 3179).	1925	do.	do.	do.	Do.
Coastal Plain Experiment Station, Tifton (in cooperation with U. S. Department of Agriculture):					
Alber (*Avena* No. 1095a, C. I. 2766).[1]	([2])	Alberto Boerger	Resistance to certain physiologic forms of crown rust.	Pure-line selection	Red oat (Red Algerian type) commonly grown in Uruguay and Argentina.
Berger (*Avena* No. 1095a 1332, C. I. 2926).	([3])	do.	do.	do.	Do.
Idaho:					
Aberdeen Substation (in cooperation with U. S. Department of Agriculture), Aberdeen:					
Hybrid selection C. I. 2574	1923	T. R. Stanton, F. A. Coffman, G. A. Wiebe, Harland Stevens, and L. L. Davis.	High yield and quality, high resistance to smut, white grain.	Hybridization	Markton × Idamine.
Hybrid selection C. I. 2577	1923	do.	do.	do.	Do.
Hybrid selection C. I. 2579	1923	do.	do.	do.	Do.
Hybrid selection C. I. 2951	1923	do.	do.	do.	Do.
Hybrid selection C. I. 2592	1923	do.	do.	do.	Markton × Victory.
Hybrid selection C. I. 2593	1923	do.	do.	do.	Do.
Hybrid selection C. I. 2599	1923	do.	do.	do.	Do.
Hybrid selection C. I. 2608	1923	do.	do.	do.	Do.
Hybrid selection C. I. 2952	1923	do.	do.	do.	Do.
Hybrid selection C. I. 2965	1923	do.	do.	do.	Do.
Selection No. 357-57 (C. I. 3230)	1924	T. R. Stanton, F. A. Coffman, and G. A. Wiebe.	High yield, smut and drought resistance.	Pure-line selection	C. I. 357 (an unnamed variety from Turkey).
Selection No. 357-124 (C. I. 3231)	1924	do.	do.	do.	Do.
Selection No. 52 (C. I. 3008)	1928	F. A. Coffman, G. A. Wiebe.	High yield, high resistance to stem rust, stiff straw.	Natural hybrid	Richland × unknown variety.
Illinois:					
Agricultural Experiment Station, Urbana:					
Illinois No. 137	1925	C. M. Woodworth	High yield, tall stiff straw, early maturity.	Pure-line selection	Sixty-Day.
Illinois No. 140	1925	do.	High yield, low percentage of hull, early maturity.	do.	Do.
Illinois No. 243	1930	R. E. Fore	Drought resistance, high yield, plump kernels.	Hybridization	Sixty-Day × Fulghum (Kansas selection No. 5396).
Iowa:					
Agricultural Experiment Station, Ames (in cooperation with U. S. Department of Agriculture):					
Iowa No. 970	1914	L. C. Burnett	High yield, adapted to early sowing	Pure-line selection	Kherson.
Iowa No. 438	1922	do.	High yield, adapted to wide range in sowing date.	do.	Do.
Iowa No. 1317	1921	do.	do.	do.	Burt.
Iowa No. 1256	1920	do.	High yield, adapted to late sowing	do.	Do.

See footnotes at end of table.

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Country, State or Province, developing institution, and strain	Year selected or hybridized	Name of breeder	Superior characters	Breeding method used	Parent material
United States—Continued					
Iowa—Continued.					
Agricultural Experiment Station, Ames—Continued.					
Iowa No. D67 (C. I. 2870)	1918	S. M. Dietz and L. C. Burnett.	Resistance to stem rust, moderate resistance to crown rust, high yield, adapted to late seeding.	Hybridization	Richland (Iowa No. 105)× Green Russian.
Iowa No. D77 (C. I. 2813)	1918	do	do	do	Do.
Hawkeye (C. I. 2464)	1918	do	do	do	Do.
Hybrid selection (XC2737) C. I. 3236.	1927	T. R. Stanton, F. A. Coffman, H. C. Murphy, L. C. Burnett, and H. B. Humphrey.	High yield, high resistance to stem rust and smut.	do	Markton × Iogold.
Hybrid selection (XC2737) C. I. 3237.	1927	do	do	do	
Hybrid selection (XC2737) C. I. 3238.	1927	do	do	do	Do.
Hybrid selection (XC2737) C. I. 3239.	1927	do	do	do	Do.
Hybrid selection (XC2737) C. I. 3240.	1927	do	do	do	Do.
Hybrid selection (XC2868) C. I. 3241.	1928	do	High yield, smut resistance, moderate resistance to crown rust.	do	Iowa No. 444 × Markton.
Hybrid selection (XC2868) C. I. 3242.	1928	do	High yield, smut and crown-rust resistance.	do	Do.
Hybrid selection (XC2868) C. I. 3243.	1928	do	High yield, smut and stem-rust resistance, moderate resistance to crown rust.	do	Do.
Hybrid selection (XC2868) C. I. 3244.	1928	do	do	do	Do.
Hybrid selection (XC2868) C. I. 3245.	1928	do	High yield, smut and stem-rust resistance.	do	Do.
Hybrid selection (XC2868) C. I. 3246.	1928	do	High yield, smut resistance, moderate resistance to crown rust.	do	Do.
Hybrid selection (XC2868) C. I. 3247.	1928	do	High yield, smut, crown, and stem-rust resistance, white grain.	do	Do.
Hybrid selection (XC2871) C. I. 3248.	1928	do	High yield, resistance to smut and stem rust.	do	Rainbow × Markton.

Hybrid selection (XC311) C. I. 3249.	1931	do	High resistance to smut and stem rust	do	Markton × Iogold (43F₃ [110-4] × Carleton.
Hybrid selection (XC311) C. I. 3250.	1931	do	do	do	Do.
Hybrid selection (X S1098)	1930	do	High resistance to crown rust, stem rust and smut.	do	Victoria × Richland.
Hybrid selection 5539 (X S1098)	1930	do	do	do	Do.
Hybrid selection 5541 (X S1098)	1930	do	do	do	Do.
Hybrid selection 5543 (X S1098)	1930	do	do	do	Do.
Hybrid selection 5544 (X S1098)	1930	do	do	do	Do.
Hybrid selection 5545 (X S1098)	1930	do	do	do	Do.
Hybrid selection 5546 (X S1098)	1930	do	do	do	Do.
Hybrid selection 5556 (X S1098)	1930	do	do	do	Do.
Hybrid selection (M X328)	1932	do	do	do	Bond × Iogold.
Victoria (C. I. 2401)	(4)	Alberto Boerger and Enrique Klein of South America.	High resistance to crown rust and smut.	Artificial or mass population of pure lines 64q, 64r, and 64t.	Common white of the country.
Bond (C. I. 2733)[5]	(6)	J. T. Pridham of Australia.	High resistance to crown rust and smut, stiff straw with excellent standing ability.	Hybridization	A sport from *Avena sterilis* × Golden Rain.
Russian selection 76 (C. I. Nos. 2508 and 2897, Zhegalov No. A4114).	(7)	S. I. Zhegalov	Awnless, nonfatuoid producing	Introduction (from U. S. S. R.).	Unknown.
Hajira (C. I. 1001)	(8)	Unknown	Early maturity, high resistance to stem rust.	Introduction (from Union of South Africa, formerly from Algeria).	Do.
Magistral (C. I. 2460)	(9)	do	Resistance to crown and stem rust, white grains.	Introduction (from U. S. S. R.).	Do.
Kansas:					
Kansas State College, Manhattan (in cooperation with U. S. Department of Agriculture):					
Hybrid selection (Kansas No. 6136, C. I. 3220).	1926	T. R. Stanton, F. A. Coffman, and John H. Parker.	Moderate smut resistance, high yield, high test weight, early maturity.	Hybridization	Fulghum × Markton.
Hays Branch Experiment Station, Hays (in cooperation with U. S. Department of Agriculture):					
Fulghum selection H. C. No. 726 (C. I. 3227).	1924	F. A. Coffman, A. F. Swanson, J. H. Parker, and T. R. Stanton.	High yield, uniformity of plant and grain characters.	Pure-line selection	Fulghum.
Fulghum selection H. C. No. 713 (C. I. 3228).	1924	do	do	do	Do.
Burt × Sixty-Day selection H. C. No. 757 (C. I. 3229).	1924[1]	J. B. Norton, F. A. Coffman, A. F. Swanson, T. R. Stanton, and C. W. Warburton.	do	Hybridization	Burt × Sixty-Day (C. I. 727).

See footnotes at end of table.

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Country, State or Province, developing institution, and strain	Year selected or hybridized	Name of breeder	Superior characters	Breeding method used	Parent material
United States—Continued					
Michigan:					
Agricultural Experiment Station, East Lansing:					
Hybrid selection C. I. 2590	([11])	T. R. Stanton, F. A. Coffman, G. A. Wiebe, and E. E. Down.	High resistance to smut, high test weight in Michigan.	Pure-line selection	Markton × Victory.
Tula (C. I. 2136)	([12])	Unknown	"A strain that has great possibilities for crossing because of its exceptionally high test weight under Michigan conditions; weight 6–9 pounds above standard varieties of State."—E. E. Down.	Introduction (from U. S. S. R.).	"No. 2306, Provnce of Tula. An improvedi variety."—Vavilov.
Minnesota:					
Agricultural Experiment Station, University Farm, St. Paul: Mindag.	1918	H. K. Hayes	High yield, stem rust resistance	Hybridization	(Minota × White Tartar [White Russian]) × Black Mesdag.
Nebraska:					
Agricultural Experiment Station, Lincoln:					
Nebraska Burt No. 518 (C. I. 2886)	1920	T. A. Kiesselbach, W. E. Lyness, and A. Anderson.	Early maturity, stem rust resistance and high yield.	Pure-line selection	Burt.
Nebraska Burt No 520 (C. I. 2888)	1920	do	do	do	Do.
Nebraska Burt No. 529	1920	do	do	do	Do.
Nebraska Strain No. 52	1920	do	High yield and smut resistance	do	Do.
Nebraska Strain No. 53	1920	do	do	do	Do.
New Jersey:					
Agricultural Experiment Station, New Brunswick:					
New Jersey No. F 29–41	1930	H. B. Sprague	High yield of both grain and straw, resistance to lodging.	do	Fulghum.
New Jersey No. F 29–43	1930	do	do	do	Do.
New Jersey No. F 29–44	1930	do	do	do	Do.
New Jersey No. K 29–33	1930	do	do	do	Kherson.

New York:					
Cornell University, Department of Plant Breeding, Ithaca (in cooperation with U. S. Department of Agriculture):					
Cornell Hybrid 428-3-29	1924	H. H. Love and W. T. Craig	High yield, thin hull	Hybridization	(Great American × Cornellian) × State sel. 133-46.
Cornell Hybrid 439-c2-18 (Hull-less).	1926	do	Smut resistance	do	(Sixty-Day × Black Mesdag) × (Hull-less × Garton No. 585).
Ohio:					
Agricultural Experiment Station, Wooster:					
Ohio No. R X F 38	1924	J. B. Park	High yield, stiff straw, white grain, early maturity.	do	Ruakura × Fulghum.
Ohio No. F X RP 225	1924	do	High yield, stiff straw, yellow grain	do	Fulghum × Red Rustproof.
Oklahoma:					
Agricultural Experiment Station, Stillwater:					
Oklahoma No. 1-32-1446	1932 [13]	T. R. Stanton, C. B. Cross, F. A. Coffman, and W. D. Mankin.	Winter resistance, plump grain	do	Hairy Culberson (C. I. 2505) × Fulghum (winter type, C. I. 2498).
Oklahoma No. 1-32-1460	1932 [13]	do	do	do	Do.
Oklahoma No. 1-32-1525	1932 [13]	do	do	do	Do.
Oklahoma No. 1-32-1546	1932 [13]	do	do	do	Do.
Oregon:					
Sherman County Branch Station, Moro (in cooperation with U. S. Department of Agriculture):					
Carleton (C. I. 2378)	1919	T. R. Stantion, F. A. Coffman, D. E. Stephens, and B. B. Bayles.	Early, high resistance to smut, high yield.	do	Sixty-Day (165-1) × Markton (357-1).
Sixty-Day × Markton C. I. 2352	1919	do	do	do	Do.
Sixty-Day × Markton C. I. 2372	1919	do	do	do	Do.
Pennsylvania:					
Agricultural Experiment Station State College: Hybrid selection (90a-27).	1918	C. F. Noll	High yield, low percentage of hull, resistance to smut.	do	Albion (Iowa No. 103, C. I. 729) × Red Rustproof (commercial strain).
South Carolina:					
Coker's Pedigreed Seed Co., Hartsville:					
Coker No. 34-11 F_5-77 (110-1-3-51-6)	1925	George J. Wilds	Early maturity, cold and smut resistance.	do	Norton (20-93) × Navarro.
Coker No. 34-14 F_5-135 (110-1-2-55-7)	1925	do	Cold and smut resistance, high yield, stiff straw.	do	Do.
Coker No. 34-20 F_5-176 (110-1-4-7-11)	1925	do	Cold and smut resistance, stiff straw, high yield.	do	Do.
Coker No. 34-4 F_5-19 (110-1-1-41-9)	1925	do	Cold and smut resistance, high yield	do	Do.

See footnotes at end of table.

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Country, State or Province, developing institution, and strain	Year selected or hybridized	Name of breeder	Superior characters	Breeding method used	Parent material
United States—Continued					
South Dakota:					
Agricultural Experiment Station, Brookings:					
South Dakota No. 165 (Hull-less, C. I. 2883).	1925	Matthew Fowlds	Stem rust and smut resistance, high yield.	Hybridization	(Markton × Richland) × (Swedish Select × Kilby Hull less).
Tennessee:					
Agricultural Experiment Station, Knoxville:					
Tennessee No. 090 (C. I. 3175)	1929	Newman Hancock	Cold resistance, high yield	Pure-line selection	Fulghum (winter type [699-2011] C. I. 2499).
Tennessee No. 1918 (C. I. 3172)	1930	do	do	do	Do.
Tennessee No. 1884 (C. I. 3169)	1930	do	do	do	Do.
Texas:					
Agricultural Experiment Station, Substation no. 6, Denton (in cooperation with U. S. Department of Agriculture):					
Texas No. 1401-24	1920	A. H. Leidigh, C. H. McDowell, and P. B. Dunkle.	High yield, stiff straw	do	Red Rustproof (Appler).
Texas No. 1118-69	1920	do	do	do	Red Rustproof.
Texas No. 2805-39	1927	P. C. Mangelsdorf and P. B. Dunkle.	do	do	Do.
Texas No. 2805-43	1927	do	do	do	Do.
Texas No. 1415-12	1927	do	do	do	Do.
Texas No. 6217-43	1927	do	do	do	Do.
Ferguson Seed Farms, Howe (formerly Sherman): Navarro (C. I. 966).	1919	A. M. Ferguson	Early maturity, high resistance to smut, short stiff straw, plump awnless grain.	Probably originated from natural hybrid.	Unknown.
Virginia:					
U. S. Department of Agriculture, Arlington Experiment Farm, Rosslyn:					
Custis (C. I. 2041)	1915	T. R. Stanton and J. W. Taylor.	Early to midseason maturity, winter resistance, high yield and quality.	Hybridization	Winter Turf × Aurora.
Hairy Culberson (C. I. 2505)	1920	T. R Stanton and C. W. Warburton.	High winter resistance	Pure-line selection	Culberson.

Culred (C. I. 3264)	1905	J. B. Norton, T. R. Stanton, and C. W. Warburton.	Winter resistance, high yield	Hybridization	Red Rustproof × Culberson.
Fulghum selection (winter type [699-202] C. I. 2498).	1920	T. R. Stanton, F. A. Coffman, and J. W. Taylor.	do	Pure-line selection	Fulghum (C. I. 699).
Fulghum selection (winter type [699-2011] C. I. 2499).	1920	do	do	do	Do.
Fulghum selection (winter type [699-2015] C. I. 2500).	1920	do	do	do	Do.
Fulghum selection (winter type, C. I. 3232).	1926	do	do	do	Fulghum (winter type selection, C. I. 2500).
Fulghum selection (winter type, C. I. 3233).	1926	do	do	do	Fulghum (winter type selection C. I. 2499).
Fulghum selection (winter type, C. I. 3234).	1926	do	do	do	Do.
Aurora (C. I. 831)	1909	C. W. Warburton and T. R. Stanton.	High quality, early maturity, stiff straw.	do	Red Rustproof (Appler).
Winter Turf selection (C. I. 3297)	1908	do	Winter resistance, high yield	do	Winter Turf.
Wisconsin:					
Agricultural Experiment Station, Madison:					
Markton × Victory (C. I. 2608)	1923 [15]	T. R. Stanton, B. D. Leith, F. A. Coffman, and G. A. Wiebe.	High resistance to smut, large kernel (caryopsis), good color.	Hybridization	Markton × Victory.
State Pride × Markton (X160)	1928	B. D. Leith	Smut resistance, early maturity	do	State Pride × Markton.
O. A. C. no. 144 × Markton (X167)	1928	do	Smut resistance, stiff straw	do	O. A. C. No. 144 × Markton.
Selection No. 12.41/29.3	1929	E. J. Delwiche	High yield	Pure-line selection	Forward.
Canada					
Quebec:					
Macdonald College, McGill University:					
Lasalle (C. A. N. No. 97)	1912	R. Summerby and E. A. Lods.	High yield and high percentage of kernel.	Hybridization	Siberian M. C. 2107 × Joanette M. C. 1207.
Action (C. A. N. No. 451)	1913	do	Very strong, pliant, whiplike straw, midseason maturity.	do	Fifty Pound Black (R) × Alaska (G).
Foster (C. A. N. No. 545)	1916	do	High yield and quality, midseason maturity.	do	O. A. C. No. 72 × Siberian M. C. 2107.
Lanark (C. A. N. No. 541)	1918	E. A. Lods and R. Summerby.	Early maturity, high yield, strong straw, few awns.	do	O. A. C. No. 72-M. C. 214 × Early Ripe M. C. 213.
Mabel (C. A. N. No. 542)	1918	do	do	do	Do.
Ontario:					
Central Experimental Farm, Ottawa:					
Ottawa No. 236	1927	R. A. Derick	Early maturity, high yield	Pure-line selection	Alaska (Commercial).
Ottawa No. 83	1927	do	Midseason maturity, high yield	do	Legacy (Ottawa No. 678).
Scott No. 50		F. M. McIsaac	High yield, widely adapted	do	Banner (Ottawa No. 049).
Hybrid No. 1827	1927	R. A. Derick	High yield and quality	Hybridization	Golden Rain × Alaska.
Dominion Rust Laboratory, Winnipeg:					
Hybrid A	1926	J. N. Welsh	Resistance to stem rust (all common physiologic forms), stiff straw.	do	"Hajira strain" × Banner.
Hybrid B	1927	do	do	do	Victory × Green Russian.

See footnotes at end of table.

Table 3.—*Summary of the development of new superior strains and stocks of oats in the United States and Canada by breeding through the application of pure-line selection to adapted old, mixed varieties grown in these countries for varying periods of years or to adapted introduced stocks, mainly from Europe, or by hybridization (and subsequent selection) of varieties, including many of the improved ones shown in tables 2 and 4*—Continued

Country, State or Province, developing intitution, and strain	Year selected or hybridized	Name of breeder	Superior characters	Breeding method used	Parent material
Canada—Continued					
Saskatchewan:					
University of Saskatchewan, Saskatoon:					
Hybrid selection (F_7)	1929	J. B. Harrington	Early maturity, high yield	Hybridization	Sunrise × Banner.
Do	1929	do	do	do	Sunrise × Victory.
Do	1929	do	Early maturity, high yield, thin hull	do	(Sunrise × Victory) × Gopher.
Do	1929	do	Early maturity, high yield, resistance to stem rust.	do	Sunrise × (Minota × White Tartar).
Hybrid selection (F_8)	1929	do	Early maturity, high yield, resistance to stem rust and smut.	do	(Sunrise × [Minota × White Tartar] × Markton).
Do	1930	do	Early maturity, high yield	do	Banner × Gopher.
Do	1930	do	do	do	Victory × Gopher.

[1] Probably similar to or identical with La Estanzuela 1095a, now grown commercially in Uruguay as shown in table 4.
[2] Introduced in 1930 from Uruguay by U. S. Department of Agriculture.
[3] Introduced in 1931 from Uruguay by U. S. Department of Agriculture.
[4] Received in 1927 by U. S. Department of Agriculture.
[5] Reported also from the Department of Agriculture, New South Wales, Australia.
[6] Introduced in 1929 by U. S. Department of Agriculture.
[7] Introduced in 1927 through C. L. Huskins by U. S. Department of Agriculture.
[8] Introduced in 1919 by U. S. Department of Agriculture.
[9] Introduced in 1927 by U. S. Department of Agriculture.
[10] Original hybrid made in 1902.
[11] Before 1929 by U. S. Department of Agriculture, at Aberdeen, Idaho.
[12] Presented to U. S. Department of Agriculture by N. I. Vavilov of the U. S. S. R. in 1924.
[13] Selected from a cross made by U. S. Department of Agriculture at the Arlington Experiment Farm, Rosslyn, Va., 1926.
[14] About.
[15] U. S. Department of Agriculture, Aberdeen, Idaho.

TABLE 4.—*Historical summary of the development of improved varieties of oats in countries other than those of North America primarily by breeding through the application of pure-line selection to superior indigenous or introduced varietal stocks, or by hybridization (and subsequent selection) of superior strains and varieties*

Country, State or Province, developing institution, and variety	Year introduced, selected or hybridized	Name of breeder	Superior characters	Breeding method used—introduction, mass or pure-line selection, or hybridization	Parent material	When distributed to farmers	Percentage of present acreage	Recommended varieties by States or Provinces
Europe								
Wales:								
Welsh Plant Breeding Station, University College of Wales, Aberystwyth:								
White Winter S. 81	1920	E. T. Jones	Stiff straw, high yield, cold resistance.	Hybridization	Kyko × Gray Winter.	1931	Unknown	Spring varieties: Record, Victory, Star, Golden Rain II, Radnorshire Sprig, Black Bell III, Ceirch du bach, and Ceirch Llwyd. Winter varieties: Gray Winter, Black Winter, White Winter S. 81, and White Winter S. 82.
White Winter S. 82	1920	do	Stiffer straw than S. 81, high yield, cold resistance.	do	do	1931	do	Do.
Ceirch Llwyd Cwta S. No. 171.	1923	do	High quality of grain	do	*Avena brevis* × *A. strigosa* [1].	1936	do	Do.
Scotland:								
Scottish Society for Research in Plant Breeding, Corstorphine, Edinburgh:								
Elder	1919	William Robb	High resistance to lodging, high yield on fertile soils, high grain quality.	do	Potato × Beseler Prolific.	1931		
Bell	1915	do	High tillering capacity, nonshattering, high yield of grain and straw on poor soils.	do	Sandy × Leader	1932		
Early Miller	1919	do	High yield, high bushel weight, resistance to lodging.	do	Potato × Record	1934		

[1] Distinct species of *Avena* of minor importance. All other varieties reported belong to *A. sativa*, *A. nuda*, or *A. byzantina*.

Table 4.—*Historical summary of the development of improved varieties of oats in countries other than those of North America primarily by breeding through the application of pure-line selection to superior indigenous or introduced varietal stocks, or by hybridization (and subsequent selection) of superior strains and varieties*—Continued

Country, State or Province, developing institution, and variety	Year introduced, selected or hybridized	Name of breeder	Superior characters	Breeding method used—introduction, mass or pure-line selection, or hybridization	Parent material	When distributed to farmers	Percentage of present acreage	Recommended varieties by States or Provinces
Europe—Continued								
Ireland:								
Albert Agricultural College, Dublin:								
Glasnevin Sonas	1911	H. Hunter	Strong straw, high yield, helminthosporium resistance.	Hybridization	Banner × Black Tartar.	1923		Victory II for ordinary soils; Glasnevin Sonas and Glasnevin Ardri for heavy soils; Glasnevin Success for late soils; Potato for west Ireland.
Glasnevin Success	1933	M. Caffrey	Strong straw, early maturity.	do	Victory × Record	1931		Do.
Glasnevin Ardri	1926	do	Strong straw, high yield	do	Sonas × Victory	1933		Do.
France:								
Institut des Recherches Agronomique, Versailles:								
Noire hybride Inversable (black hybrid inversable)	1910	M. Schribaux	Resistance to lodging, high ield	do	Ligowo × Brie	1922	Much cultivated in many regions.	Victorie (Victory), Aigle (Eagle), Etoile (Star), Von Lochow, Ligowo, Mansholt III, Noire hybride. Vilmorin (black Hybrid Vilmorin).
Prolifique Blanche (white prolific).	1919	do	Early maturity, resistance to lodging.	do	Erifolium × (Ligowo × Brie) 147.	1928	Grown in Limague.	Grignonnaise, Hybride noire Inversable for rich soils, Noire trés hative (Vilmorin) for dry soils, Von Lochow, and Mansholt III.
Noire Précoce de Noisy (early black of Noisy).	1919	do	Very early maturity, very high percentage of kernel.	do	Daubeney × (Ligowo × Brie)-186.	1932	do	Do.
Avoine de Versailles (Versailles).	1919	do	Early maturity, very high percentage of kernel, high yield.	do	Houdan × Noire hybride Inversable.	1932	do	Do.

Station d'Amélioration des Plantes de Grande Culture, à Dijon: Grignonnaise.	1922	Ch. Crepin	High yield, stiff straw, small grain.	do	Grise de Houdan × 176-7 (line out of Hybride noire Inversable of M. Schribaux).	1932	do	Do.
Netherlands:								
Westpolder Gem. Ulrum, Groningen:								
Mansholt Binder	1925	R. J. Mansholt	Very short stiff straw, high yield.	Pure-line selection.	Carsten III	1931	60	
Mansholt III	1909	do	Stiff straw, high yield	Hybridization.	Victory (Svalöf) × Mansholt II.	1920	40	
Sweden:								
Swedish Seed Association, Svalöf:								
Stormogul I, Svalöf No. 0450 (Great Mogul).	1892	Hjalmar Nilsson	High yield, late maturity	Pure-line selection.	Black Tartar	1901-32	3	
Guldregn I, Svalöf No. 0386 (Golden Rain).	1892	do	Midseason maturity, stiff straw.	do	Probsteier (Milton)	1903-32	5	
Ligowo II, Svalöf No. 0353.	1892	do	Large white grain, good color.	do	Ligowo (Vilmorin).	1904	Less than 3	
Seger, Svalöf No. 0355 (Victory).	1892	do	High yield and quality	do	Milton	1908	20	
Klock II, Svalöf No. 0408 (Bell II).	1898	N. H. Nilsson-Ehle.	Large white grain, high tillering capacity, relatively early maturity.	Natural cross.	Out of Golden Rain (Probably Golden Rain × Klock I).	1919-23	5	
Klock III, Svalöf No. 01143 (Bell III).	1906	do	High yield	Hybridization.	Klock II × Stormogul.	1917-31	Less than 3	
Vit Odal, Svalöf No. 01164 (White Allodial).	1906	N. H. Nilsson-Ehle and Å. Åkerman.	Earlier than Golden Rain, stiff straw.	do	Golden Rain × Dala.	1926	do	
Stjärn Svalöf No. 01182 (Star).	1908	L. Walstedt	A little earlier and better straw strength than Victory.	do	Seger × Kron	1927	5	
Orion II, Svalöf No. 01104.	1903	N. H. Nilsson-Ehle and A. Uhlander.	Better straw strength and higher yield than Orion I.	do	Ligowo × No. 0668.	1927	5	
Guldregn II, Svalöf No. 01121 (Golden Rain II).	1908	Å. Åkerman	Higher yield and larger grain than Golden Rain I.	do	Golden Rain I × Victory.	1928	35	
Svart Plym, Svalöf No. 01192 (Black Plume).	1907	N. H. Nilsson-Ehle and Å. Åkerman.	Better quality than Black Tartar.	do	0210 (out of Black Tartar) × 0298 (out of natural cross Black Tartar × Probsteier).	1930	Less than 1	

TABLE 4.—*Historical summary of the development of improved varieties of oats in countries other than those of North America primarily by breeding through the application of pure-line selection to superior indigenous or introduced varietal stocks, or by hybridization (and subsequent selection) of superior strains and varieties*—Continued

Country, State or Province, developing institution, and variety	Year introduced, selected or hybridized	Name of breeder	Superior characters	Breeding method used—introduction, mass or pure-line selection, or hybridization	Parent material	When distributed to farmers	Percentage of present acreage	Recommended varieties by States or Provinces
Europe—Continued								
Sweden—Continued.								
Swedish Seed Association, Svalof—Contd.								
Örn, Svalöf No. 01272 (Eagle).	1914	Å. Åkerman	Very high yield, stiff straw.	Hybridization	Seger × von Lochow Gelbhafer (from Germany).	1931	5	
Engelbrekt II, Svalöf No. 01151 (from 01140).	1906	N. H. Nilsson-Ehle and R. Torssell.	Higher yield and stiffer straw than Engelbrekt I.	do	Klock II × Stormogul.	1931	Less than 3	
Sirius, Svalöf No. 01210.	1918	Å. Åkerman	Early maturity, good grain quality.	do	01180 (out of Seger × Kron) × Klock II.	1932	Less than 1	
Stormogul II, Svalöf No. 01140b.	1906	N. H. Nilsson-Ehle and R. Torssell.	Higher yield and stiffer straw than Stormogul I.	do	Klock II × Stormogul.	1932	Less than 3	
Extra-Klock, Svalöf No. 01310 (Extra-Bell).	1918	Å. Åkerman	Larger grain and a little earlier than Klock II.	do	Seger × Klock III	1933	do	
Ligowo III, Svalöf No. 01400.	1920	do	Stiffer straw than Ligowo II.	do	01173 (Seger × Yellow Naesgaard) × Ligowo II.	1934	do	
Swedish Seed Association, Branch Station, Lulea: Orion C, Svalöf No. 01102.	1903	A. Uhlander	Stiffer straw than Orion I.	do	Ligowo × 0668	1934	do	
Weibullsholm Plant Breeding Institute, W. Weibull, Ltd., Landskrona:								
Arla (Early)	1911	H. Heribert-Nilsson	Early maturity, relatively high yield, "high grain content", stiff straw.	do	Leutewitzer Gelbhafer × Svalöf Guldregn I.	1922		
Argus	1913	do	High yield, large grain, straw stiff, midseason maturity.	do	Svalöf Seger × a pure line of Svalöf Stormogul.	1926		

Diamant (Diamond)	1912	do	High yield and quality, low hull percentage, white grain.	do	Abundance × Svalöf Seger.	1928		
Bambu (Bamboo)	1924	H. Heribert-Nilsson, G. Turesson, and E. Akerberg.	Relatively high yield, "grain content and hull weight high," early maturity, relatively good resistance to gray spot disease.	do	3602 (out of Abundance × Svalöf Seger) × 7284 (out of Seger × a pure-line of Svalöf Stormogul.)	1934		
Germany:								
F. von Lochow-Petkus (Station der Kleinbahn des Kreises Jüterbog-Luckenwalde) Petkus: Gelbhafer.	1903	F. von Lochow-Petkus.	Adapted to all kinds of soil, especially suitable for dry sections.	Pure line selection.	Commercial variety	1909	40	Von Kameke Streckenthiner 9, Dippes früh weiss (Early White Dippes), Peragis weiss (White Peragis), Hohenheimer weiss (White Hohenheimer), F. von Lochows Gelbhafer (Lochows Yellow), P. S. G. Gold-Korn (P. S. G. Gold grain).
Asia								
India:								
Imperial Department of Agriculture in India, Pusa:								
B. S. No. 1	1924	F. J. F. Shaw and R. D. Bose.	Early maturity, high yield, smut and drought resistance.	do	Bihar (mixed population).	1928	Exact area not known but these varieties are grown all over North Bihar and in different parts of India.	B. S. No. 1, B. S. No. 2, Hybrid C, Hybrid J, and Hybrid G.
B. S. No. 2	1924	do	Early maturity, high yield, drought resistance, moderate smut resistance.	do	do	1928	do	Do.
Hybrid C	1926	do	Midseason maturity, high yield, plump grain, stiff straw.	Hybridization	Scotch Potato × Pusa.	1931	do	Do.
Hybrid J	1926	do	do	do	do	1931		
Hybrid G	1926	do	Midseason maturity, high yield, plump grain, stiff straw, small second grain, thin hull.	do	do	1931		

TABLE 4.—*Historical summary of the development of improved varieties of oats in countries other than those of North America primarily by breeding through the application of pure-line selection to superior indigenous or introduced varietal stocks, or by hybridization (and subsequent selection) of superior strains and varieties*—Continued

Country, State or Province, developing institution, and variety	Year introduced, selected or hybridized	Name of breeder	Superior characters	Breeding method used—introduction, mass or pure-line selection, or hybridization	Parent material	When distributed to farmers	Percentage of present acreage	Recommended varieties by States or Provinces
Africa								
Agricultural Experiment Station, Salisbury, Southern Rhodesia:								
S. E. S. No. 52	1926	H. C. Arnold	Stem rust and drought resistance.	Pure-line selection.	"Burt" (so reported).	1931	80 of spring-sown crop.	S. E. S. No. 52.
K. H. C. No. 2	1929	do	Stem rust resistance	Hybridization	Kherson × (Liberty Hull-less × Kherson).	1932	10 of spring-sown crop.	Do.
South America								
Uruguay:								
Instituto Fitotechnico y Semillero Nacional, La Estanzuela, Colonia:								
La Estanzuela No. 64s.	1915	Alberto Boerger and Enrique Klein.	Resistance to crown rust and smut, early maturity, high yield of grain and pasturage.	Pure-line selection.	"Criolla," a mixed population grown in Uruguay.	1918	Approximately 70,000 hectares.	
La Estanzuela No. 1095a.	1927	Alberto Boerger	Resistance to crown rust and smut, high yield.	do	Red oat commonly grown in Uruguay and Argentina.	1930	Unknown	
La Estanzuela No. Bid.	1924	do	Resistance to crown rust and smut, high yield.	Hybridization.	La Estanzuela 64s × La Estanzuela 64t.	1934		
Australia								
Victoria:								
Department of Agriculture, Agricultural Division, Melbourne, C2:								

Palestine	1920	G. S. Gordon	Early maturity, high yield, high percentage of grain to straw, drought resistance, high palatability to stock.	Pure-line selection.	Introduction (from Palestine).	1925	1.4 (21197 acres).	Algerian, Mulga, Palestine, Dawn, Belar, and Guyra.
Dawn	1922	do	Plump grain, suitable for soiling, silage, and hay, high palatability to stock, good early growth.	do	Sunrise	1929	.03 (510 acres)	Do.
New South Wales: Department of Agriculture, Box 36A, G. P. O. Sydney:								
Algerian	1918	J. T. Pridham	High yield of grain, hay, and pasture.	Hybridization	Algerian (introduced from Algeria) × Red Rustproof.	1925	50	Algerian, Belar, Gidgee, Mulga, Buddah, Guyra, Myall, Laggan, Burke, Kareela, Fulghum, Palestine, and White Tartar.
Belar	1918	do	High milling quality, strong straw, smut resistance.	Pure-line selection.	Sunrise	1920	25	Do.
Gidgee	1915	do	High yield	Hybridization	White Ligowo × Algerian.	1921	10	Do.
Mulga	1918	do	Early maturity, smut resistance.	Pure-line selection.	Sunrise	1921	5	Do.
Buddah	1919	do	Crown rust resistance	do	do	1921	2.5	Do.
Guyra	1907	do	Early maturity, smut resistance.	Hybridization	White Ligowo × Algerian.	1913	2	Do.
Sunrise	1909	do	Early maturity, good grain quality.	Pure-line selection.	Algerian	1914	1	
Myall	1917	do	Smut resistance	do	Sunrise	1919	Small	
Laggan	1922	do	Stem rust resistance	do	Kelsall	1925	do	
Burke	1926	do	do	do	Kherson (introduced from U. S. A.).	1928	do	
Kareela	1926	do	High yield of grain, good recovery after grazing.	do	Fulghum (introduced from U. S. A.).	1929	do	
New Zealand: Canterbury Agricultural College, Lincoln:								
College Algerians No. A86.	1917	F. W. Hilgendorf	High yield of grain and green feed.	do	Commercial Algerians.	1923	50	
College Algerians No. B49.	1921	do	do	do	do	1927	50	

TABLE 5.—*Summary of the development of new superior strains and stocks of oats in countries other than those of North America by breeding through the application of pure-line selection to indigenous or introduced mixed varieties or stocks or by hybridization (and subsequent selection) of varieties, including some of the improved ones shown in tables 2 and 4*

Country, State, or Province, developing institution, and strain	Year selected or hybridized	Breeder	Superior characters	Breeding method used	Parent material
Europe					
Wales:					
Welsh Plant Breeding Station, Aberystwyth:[1]					
Ceirch-du-bach S. 79	1920	Martin Jones	Increased yield over Ceirch-du-bach	Pure-line selection	Ceirch-du-bach (commercial).
Ceirch-du-bach S. 80	1920	do	do	do	Do.
Ceirch Llwyd S. 76 (*Avena strigosa*).	1922	do	Resistance to lodging, increased yield	do	Ceirch Llwyd (commercial).
Ceirch Llwyd S. 78 (*A. strigosa*).	1921	do	do	do	Do.
England:					
University of Cambridge, School of Agriculture, Cambridge: Resistance.		H. Hunter	High yield, stiff straw, adapted to soils of high fertility.	Hybridization	Gray Winter × Argentine.
Ireland:					
Albert Agricultural College, Glasnevin:					
Sonas Marvellous	1926	M. Caffrey	Strong straw, high yield	do	Sonas × Marvellous.
Fluirse	1922	do	Winter resistance	do	Banner × Wexford Tawny.
Norway:					
Felleskjøpets Stamsedgård, Hjellum:					
No. 21-2-1075	1926	H. Wexelsen	Early maturity, high yield, low hull percentage.	do	Grenader (Norwegian) × Klakka (Klock II, Svalöf).
No. 21-2-2107	1926	do	do	do	Do.
No. 24-2-22	1930	do	Early maturity, high yield, stiff straw	do	Odin (Norwegian) × Perle (Norwegian).
Germany:					
F. von Lochow-Petkus (Station der Kleinbahn des Kreises Jüterbog-Luckenwalde), Petkus: Flämingsgold.	1921	F. von Lochow-Petkus	Early maturity, 7 percent greater in yield, more uniform, and longer grains than Gelbhafer.	do	White variety (commercial) from Oberschlesien × von Lochow Gelbhafer.
France:					
Station d'Amélioration des Plantes de Grande Culture à Dijon:					
Hybrid line (in F_{11})		Charles Crepin	Stiff straw, high percentage of kernel (caryopsis), early maturity.	do	Von Lochow × line 176-7.

Hybrid line (in F_9)		do	do	do	Soldanelle (Swiss oat) × Hybride noire Inversable.
Naine noire	1922	do	Stiff straw, early maturity	do	Grise de Houdan × line 1767–(out of Hybride noire Inversable of Schribaux).
Naine grise	1922	do	do	do	Do.
Vilmorin-Andrieux et Cie., Paris: Black Mesdag.		Louis de Vilmorin	Early maturity, smut resistance	Pure-line selection	Black President (from Netherlands, into which country it was introduced from the Baltic Provinces about 1870)
Asia					
India:					
Imperial Department of Agriculture of India, Pusa:					
Hybrid X	1928	R. D. Bose	Early maturity, high yield, long grains, thin hull, heavy stooler, smut resistance, suitable for soiling.	Hybridization	Albion (Iowa No. 103) × Pusa B. S. 1.
Hybrid Y	1929	do	Midseason, otherwise same as Hybrid X.	do	Pusa B. S. 2 × Kinwade.
Hybrid Z	1929	do	Fairly early maturity, high yield, very plump grain.	do	(Scotch Potato × Pusa B. S. [Hybrid II, 308]) × (Abundance × Pusa B. S. 4 [Hybrid III, 242]).
Australia					
Victoria:					
Department of Agriculture, Agricultural Division, Melbourne C 2:					
Lincoln Algerian	1920		High yield of grain and hay, general purpose variety.	Introduction (from Lincoln Agricultural College, New Zealand).	
Hybrid (serial number not reported).		G. S. Gordon	do	Hybridization	Kanota × (Wild × Ruakura).
Do.		do	do	do	Belar × Palestine.
New South Wales:					
Department of Agriculture, Sydney:					
Dun			Cold resistance, good recovery after grazing, thin hull.	Introduction (from New Zealand).	Unknown.
Amery	1921	J. T. Pridham	Smut resistance	Hybridization	*Avena sterilis* × White Ligowo.
Baxter	1920	do	do	do	Abruzzes × Victory.
Lampton	1919	do	High yield, high stem rust resistance	do	Abruzzes × (Victory × Reid).
Bombo	1918	do	High yield, strong straw, many spikelets per panicle.	do	Abruzzes × Victory.
Bradley	1926	do	Smut resistance	do	An Iowa selection × Green Russian (introduced from U. S. A.)
Bimbi	1922	do	do	do	Abruzzes × (Victory × Reid).
Woodford	1922	do	Crown rust resistance	do	*Avena sterilis* × Golden Rain.
Kurri	1926	do	Strong straw	Pure-line selection	Kelsall.
Birdwood	1921	do	Stem rust resistance, moderate crown rust resistance.	Hybridization	Sunrise × Reid.

[1] Gwilym Evans is the present custodian of the material reported on for Aberystwyth.

TABLE 5.—*Summary of the development of new superior strains and stocks of oats in countries other than those of North America by breeding through the application of pure-line selection to indigenous or introduced mixed varieties or stocks or by hybridization (and subsequent selection) of varieties, including some of the improved ones shown in tables 2 and 4*—Continued

Country, State, or Province, developing institution, and strain	Year selected or hybridized	Breeder	Superior characters	Breeding method used	Parent material
Australia—Continued.					
New South Wales—Continued. Department of Agriculture, Sydney—Continued.					
Bond	1920	J. T. Pridham	High resistance to crown rust	Hybridization	*Avena sterilis* × Golden Rain.
Westdale	1922	do	Stem rust and smut resistance, large grain, stiff straw.	do	Sunrise × Reid.
Weston	1922	do	Smut resistance, large grain, stiff straw.	do	Do.
Burdett	1920	do	Smut resistance		Unknown (from Glen Innes).
Mindag selection	1928	H. K. Hayes and J. T. Pridham.	Resistance to stem rust and smut	Hybridization (selection from unfixed material imported from Minnesota).	(Minota × White Tartar [White Russian]) × Black Mesdag.

RESEARCH WORKERS

The following list includes mainly the breeders and workers employed by institutions that returned questionnaires on superior germ plasm in oats. Nearly all the workers listed as State agricultural experiment station employees, especially for the United States, devote only a small part of their time to oat-breeding investigations. The remainder of their time is given to investigations on other crops. This is also true of a large percentage of the field staff of the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture. The names of oat breeders listed for foreign countries were all given in the returned questionnaires.

Personnel of Federal, State, and Province Research Institutions Engaged in Oat Improvement Work

[NOTE.—Names on left denote present workers; names on right denote earlier workers]

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Department of Agriculture, Bureau of Plant Industry, Division of Cereal Crops and Diseases, Washington, D. C.

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	E. F. Cauthen.

Agricultural Experiment Station of the University of Arizona, Tucson

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Agricultural Experiment Station of the University of Arkansas, Fayetteville

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L. C. Kapp.	Martin Nelson.
C. Roy Adair (Stuttgart).[10]	

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	Ruth F. Allen (Berkeley).

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Dwight Koonce.	Breeze Boyack.
D. C. Anderson.	W. W. Austin.
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	Wilson G. Shelley (Akron).
	Clyde McKee (Akron).
	Charles H. Clark (Akron).
	George A. McMurdo (Akron).
	Franklin A. Coffman (Akron).

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J. P. Camp.
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[10] Full time U. S. Department of Agriculture worker who devotes only part time to oat improvement.

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S. J. Hadden (Experiment).
Harry S. Garrison (Tifton).[10]
R. R. Childs (Athens).

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Fred Griffee
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[10] Full time U. S. Department of Agriculture worker who devotes only part time to oat improvement.
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R. W. May (Moccasin).
B. B. Bayles (Moccasin).

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J. Allen Clark (Dickinson).
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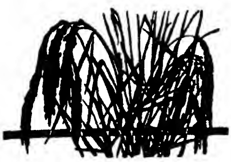
Improvement in Rice



By Jenkin W. Jones, Senior Agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry

RICE is the principal food of about half the people in the world, and it may be said that rice and wheat together are the most important of the world's grain crops. In 1933–34 the world production of milled rice was some 211,280,000,000 pounds, or about 105 pounds for every man, woman, and child on earth. Including estimates for China, world production of rough rice in 1934 was more than 7½ billion bushels.[1] Accurate figures are not available on the number of people who are largely dependent on rice as their chief energy food, but it is generally assumed to include a large part of the population of China, India, Japan, Chosen, Taiwan, Ceylon, Indochina, Siam, the Dutch East Indies, the Philippine Islands, Malaya, and Madagascar.

While rice is grown primarily for food, the byproducts obtained in milling and also the straw are used in various ways. Brown and milled rice is consumed largely in the boiled state as a vegetable or dessert, and in such breakfast foods as mush, puffed rice, and rice flakes. Broken rice is used as a food and feed, also in the brewing of fermented beverages and the manufacture of starch. Rice starch is a basis of most face powders. Rice bran and polish are used largely for feed. Polish also is used as a filler for sausage, and in the manufacture of buttons. Rice hulls often are used in rice mills as fuel; as a source of cellulose for making cardboard, rayon, and linoleum; for packing purposes; as a soil mulch; and in the manufacture of certain gases. Rice straw is commonly used for thatching roofs of buildings in Japan and China; for making paper, cardboard, mats of various kinds, sandals, hats, coats, baskets, brooms, ropes, bags; as a packing material, as a fuel, as a mulch, as a feed, and as a fertilizer.

The principal rice-producing countries of the world are located on the continent of Asia and the adjacent islands, and they lie for the

[1] The figure is 7,573,000,000 bushels, obtained by converting world production of clean rice, as given by the Yearbook of the U. S. Department of Agriculture, 1935, into rough rice on the assumption that clean rice is equal to 62 percent of the rough rice grown. The standard weight of a bushel of rough rice is 45 pounds. Rough rice is rice which has the kernels enclosed by hulls. One hundred pounds of rough rice is assumed to yield about 62 pounds of milled or clean rice, that is, rice with the hulls, kernel coats, and germs removed.

most part between the Equator and 30° north latitude. In these tropical and semitropical regions rice is by far the most dependable and productive cereal crop that can be grown. Most of the crop is grown under irrigation, often by intensive methods, and on lands that are too low and wet for the production of other cereals.

Production in the United States and Abroad

IN 1933–34, it is estimated that China produced about 38½ million short tons of clean rice; India, 34 million; Japan, over 11 million; Indochina, over 4 million; Java and Madura, over 4 million; Siam, about 3½ million; Chosen, about 3 million; the Philippine Islands, about 1½ million (1931–32); and Taiwan, over 1 million. In the same year, production in the United States was about 500,000 short tons, Italy 400,000, Egypt 360,000, and Spain 200,000.

The chief sources of the world's supply of export rice are British India (especially Burma), Indochina, and Siam. Italy, the United States, Spain, and Egypt are the principal exporters outside Asia. The average annual exports of milled rice during the 5-year period 1925–29 were for British India about 2½ million short tons, Indochina 1¾ million, and Siam 1⅓ million. In the same period the annual exports from Italy were about 215,000 tons, the United States 126,000 Spain 58,000, and Egypt 50,000.

British India (particularly Burma), Indochina, and Siam produce much more rice than is required for home consumption, whereas China, Japan proper, the Dutch East Indies, Ceylon, Malaya, and the Philippine Islands normally depend upon imports to meet their full requirements.

In the United Kingdom, Germany, France, Belgium, the Netherlands, Greece, Sweden, and Denmark, American rice is marketed in competition with that from Asia, Italy, Spain, and Egypt. Usually American rice commands a higher price in the above markets than the rice from competing countries.

In the 5-year period 1925–29 the average annual exports of rice from the United States were about 250 million pounds, or roughly one-fourth of the annual crop.

POSSIBILITIES FOR INCREASING THE YIELD IN THE UNITED STATES

The production of rice in the United States could be materially increased if markets were available at satisfactory prices. In the States bordering the Gulf of Mexico it has been estimated that from 3 to 10 million acres of land are suitable for rice culture. In the interior valleys of California also the acreage could be materially increased.[2] It does not appear, however, that the acreage should be increased unless there is a considerable increase in per capita consumption, or unless the surplus can be profitably marketed in competition with relatively cheap Asiatic rice. The tendency has been

[2]The average acreage of rice harvested in Louisiana, Texas, Arkansas, and California in the 5-year period 1927–31 was 954,000 acres, and the average production was 43,651,000 bushels.

rather the other way. The maximum acreage harvested in the United States was 1,300,000 acres in 1920, but in 1934 the acreage had decreased to 781,000 acres.

Though American rice usually commands a premium because of its quality, yields in this country are relatively low. In 1934 the average acre yield of rough rice in Louisiana was 40.5 bushels, in Arkansas 51, in Texas 53, in California 73; and the average for the 4 States was 49 bushels. By contrast, the average yields in Spain, which ranks

RICE *improvement in the principal producing countries of the world has been in progress for many years. Exporting countries in the Far East are now emphasizing improvement in quality as well as yield, so that their product may be better able to compete in the world markets with rice from Italy, Spain, the United States, and other temperate regions.*

The high acre yields of rice in some foreign countries as contrasted with the relatively low yields in the United States indicate the possibilities for further increasing average yields in this country. This is a major objective of breeding work. In addition to increased yield, improved varieties should have stiff straw, disease resistance, and good milling and table quality, and they should mature early enough to be satisfactorily harvested without danger of loss owing to inclement weather.

There is no apparent reason why it should not be possible by hybridization to develop varieties that possess all, or nearly all, the important characters that are desired by producers, millers, and consumers.

first in this respect, are reported to range from 110 to 120 bushels per acre. In 1933–34 the average acre yield in Italy was 94, in Japan proper 83, in Egypt 60, and in India proper 27 bushels.

The high average yields in Spain, Italy, and Japan are not due solely to the use of improved varieties, but also to the rather intensive methods used in growing the crop. Nevertheless, the high yields in these countries indicate the possibilities for further increasing average yields in the United States. This is a major objective of breeding work. In addition to increased yield, improved varieties

should have stiff straw, disease resistance, and good milling and table quality, and they should mature early enough to be satisfactorily harvested without danger of loss owing to inclement weather.

Before taking up this breeding work, it would be well to review briefly the historical background of rice growing in the United States and the methods of culture employed in this country, since these affect the breeding program.

History, Regions, and Culture in the United States

RICE probably originated in the area extending from southern India to Cochin China. Here the tropical climate, heavy rainfall, and large flat areas of marshy land are suitable for the growth of the plant, and wild rices still persist in this region. Watt [3] believes that rice cultivation may have spread from this region eastward to

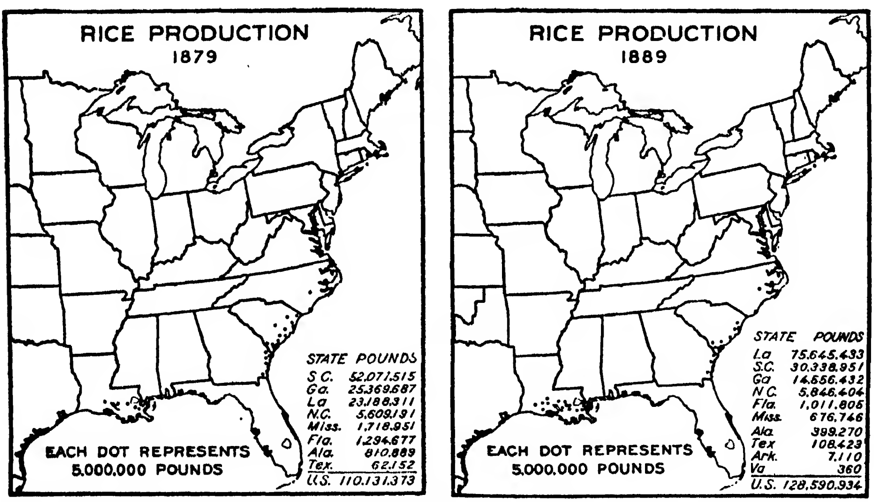


FIGURE 1.—Rice production in 1879 and 1889. The map for 1889 shows the first important shift in rice production from the South Atlantic States to the prairies of Louisiana.

China, probably 3,000 years before the Christian era, and possibly at a slightly more recent date westward and northward throughout India to Persia and Arabia, and ultimately to Egypt and Europe.

In the United States, rice production developed from an experimental seeding made at Charleston, S. C., about 1685. From South Carolina the crop moved into North Carolina and Georgia and later into Alabama, Mississippi, and Florida. The colonial population was so limited that by 1770 about 76 million pounds of clean rice were exported.

As late as a hundred years ago, in 1839, most of the rice was grown in South Carolina, North Carolina, and Georgia. South Carolina

[3] WATT, G. DICTIONARY OF ECONOMIC PRODUCTS OF INDIA. v. 5, pp. 498-654. London and Calcutta, 1891.

produced about 70 percent of the crop, and Louisiana less than 4 percent. In 1849 South Carolina, North Carolina, and Georgia still produced 90 percent of the total crop, of which 60 percent was grown in South Carolina. The Civil War adversely affected the production of rice in the South Atlantic States. A shortage of funds and labor made the crop less profitable, and the acreage decreased. After the war there was a rapid increase in the acreage along the Mississippi River in Louisiana. However, the crop did not become important here until about 1887, when it was determined that rice could be grown profitably by irrigation on the prairies located in the southwestern part of the State.

In 1889 Louisiana became, and still is, the leading State in rice production. From Louisiana, rice growing extended to the prairies of southeastern Texas about 1900, and in 1905 to the prairies of eastern Arkansas. Investigations begun by the United States Department of Agriculture in the spring of 1909 and continued for 3 years provided information that indicated the commercial possibilities of rice culture in California, and the first commercial crop was grown as short a time ago as 1912, in the Sacramento Valley.

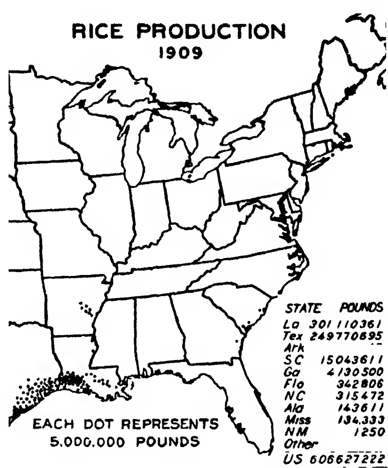


Figure 2.—Rice production in 1909. In that year Louisiana and Texas produced about 90 percent of the rice grown in the United States, and rice was being grown in Arkansas.

For over 200 years, from about 1685 until 1888, the rice crop of the United States was produced largely on the delta lands of the South Atlantic States. Then came one of the major shifts that sometimes affect agricultural products. Very little rice is now grown in the original area, and the commercial crop is produced far to the westward, in Louisiana, Texas, Arkansas, and California. In certain areas in these four States rice can be grown more profitably than any other crop for which there is a ready market. It is the principal cash crop in many counties and parishes.

CHARACTERISTICS OF THE RICE REGIONS

Contrary to popular opinion, rice is not grown in the United States on low marshy land but on irrigated level land of a rather heavy texture, underlain at from 1½ to 5 feet from the surface by an impervious subsoil. The loss of water by seepage through such soils is small. The land on which the rice crop is grown is normally submerged from 4 to 8 inches deep from the time the seedlings are about 6 to 10 inches high until the crop is ready to drain for harvest prior to full maturity, a period of 3 to 5 months. Civil engineers are employed to locate the levees. These are constructed on contour lines so that they separate the fields into subfields on which water can be held at the desired depths. On typical rice soils it requires from 4 to 5 acre-feet of water to produce a crop, whereas on light soils as much as 13 acre-feet may be needed.

The principal factors which limit the growing of rice in this country to more or less definite regions are the necessities for favorable temperatures, a constant water supply for irrigation, and suitable soils. Rice can be successfully grown only in regions that have a mean temperature of about 70° F. or above during the entire growing season of 4 to 6 months. A dependable supply of fresh irrigation water is essential for maximum yields. It may be obtained from snow-fed rivers, from a well-distributed annual rainfall on the watersheds of streams that pass through the rice areas, or from underground sources.

Chambliss[4] states:

The principal rice region of the United States lies on the Gulf Coastal plain, where there are broad, level prairies extending approximately from Rayne, La., to Crosby, Tex. These tracts of level land are broken here and there by sluggish streams. From them the irrigation water is obtained by powerful pumps. As these streams are much lower than the prairies, they also serve as natural outlets for drainage. Deep wells also are used in this section to supply irrigation water * * *. There is a similar, though smaller, prairie district in eastern Arkansas, approximately 50 miles wide and 150 miles long * * *.

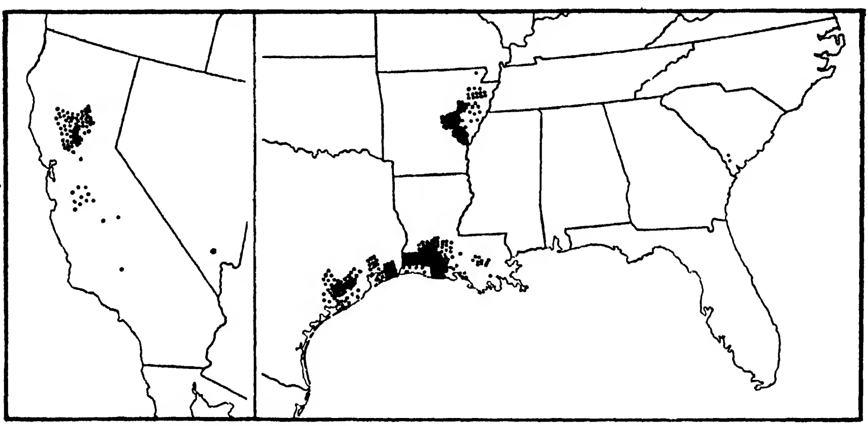


FIGURE 3.—Rice acreage in 1929. Each dot equals 1,000 acres.

Here most of the rice in Arkansas is produced. In this section water for irrigation is obtained from wells. In the Sacramento and San Joaquin Valleys of California rice is grown on comparatively level, heavy soils. The irrigation water for this area is obtained largely from the Sacramento and Feather Rivers by gravity and pumps. Most of the California crop is produced in the Sacramento Valley.

MACHINE METHODS USED IN PRODUCTION

In the United States rice is grown in essentially the same manner as wheat, oats, and barley, except that the crop is irrigated. Farm machinery is used as extensively as in the growing of other cereals.

In the Southern States, gently sloping levees are used, and in seedbed preparation, seeding, and harvesting each field is worked as a unit, for all the necessary types of machinery pass readily over the broad levees. Good seedbeds are prepared by plowing, disking,

[4] CHAMBLISS, C. E. PRAIRIE RICE CULTURE IN THE UNITED STATES. U. S. Dept. Agr. Farmers' Bull. 1092, 26 pp., illus. 1921.

harrowing, and dragging. The rice is sown usually in April and May with a grain drill or broadcast seeder. Usually there is sufficient moisture in the soil or supplied by rains to germinate the seed and maintain growth until the fields are submerged. When mature, the crop is harvested with a rice binder, shocked in the field, and threshed from the shock.

In California, however, the levees are relatively narrow and high, and in seedbed preparation and harvesting each check field or subfield is worked separately. In order to control weeds, a continuous submergence method of irrigation is used. Seedbeds are prepared by spring plowing and dragging, and the rice is sown broadcast in April and May either in the water after the fields are submerged, or on dry ground. In the latter case, the fields are submerged after sowing. The water is not removed until the rice is approaching maturity. In seeding on dry ground or in the water, horses, tractors, or airplanes may be used. When mature, the crop is harvested with rice binders, or it may be cut with swathers. After drying it is threshed with combines equipped with pick-up attachments. Some of the crop is directly combined, as are other small grains in California.

In the Orient, these large-scale machine methods are not employed. Only a small area is cultivated per farm. Work animals are used, when available, in the preparation of the land. The rice is sown mostly in small, well-prepared seedbeds, where it is given the best of care and allowed to grow for 25 to 40 days. The seedlings are then pulled and transplanted by hand from 3 to 6 inches apart in rows spaced 8 to 12 inches apart. The transplanted fields are usually kept submerged until the rice is ready to drain for harvest, though they may be drained and weeded at intervals. The crop is harvested with a hand sickle and tied into small bundles. When dry, the grain is threshed by treading on threshing floors, or by flailing. In Japan, small hand- or foot-powered threshers are used. Some large rice mills have modern threshers and thresh bundles of rice purchased directly from growers.

Practical Objectives Sought in Rice Breeding

IN SPITE of its importance from the world standpoint, rice is a minor crop in the United States. The breeding of rice has therefore received less attention in this country than that of our major cereal crops—wheat, corn, oats, and barley. Nevertheless, worthwhile work has been done with the plant because of its major importance in certain regions.

The primary objects of the present cooperative rice-breeding program of the Department of Agriculture and the State experiment stations [5] is to develop varieties that are resistant to diseases, that do

[5] Those engaged in this work include: Jenkin W. Jones, Bureau of Plant Industry, Division of Cereal Crops and Diseases, Washington, D. C.; C. Roy Adair,* Rice Branch Experiment Station, Stuttgart, Ark.; G. H. Banks, Agricultural Experiment Station, Stuttgart, Ark.; H. M. Beachell,* Agricultural Substation No. 4, Beaumont, Tex.; E. M. Cralley, Agricultural Experiment Station, Fayetteville, Ark., Loren L. Davis,* Biggs Rice Field Station, Biggs, Calif.; J. Mitchell Jenkins,* Rice Experiment Station, Crowley, La.; N. E. Jodon,* Rice Experiment Station, Crowley, La.; B. M. King,* Agricultural Experiment Station, Columbia, Mo.; E. C. Tullis,* Agricultural Experiment Station, Fayetteville, Ark.; and R. H. Wyche, Agricultural Experiment Station, Beaumont, Tex.

* Denotes cooperative employees.

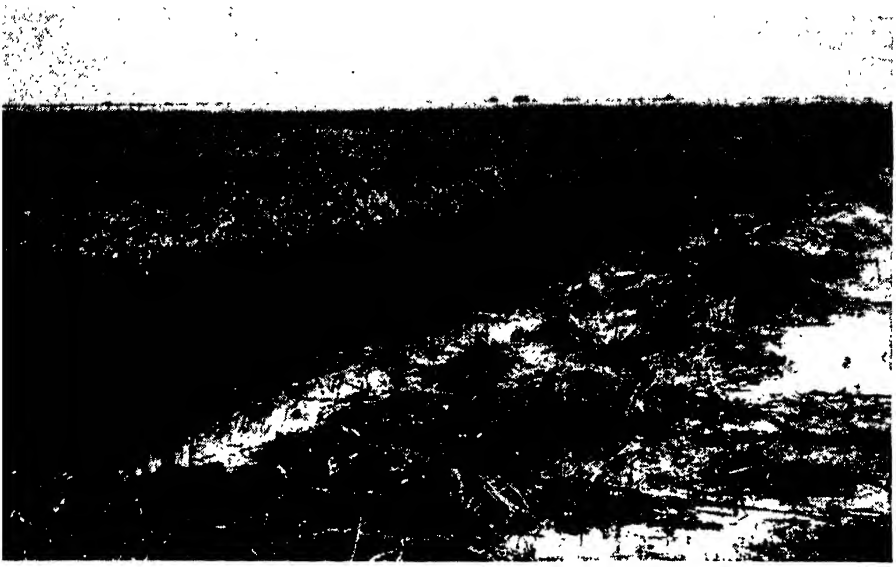


FIGURE 4.—A rice field in California.

not lodge or shatter, that mature at the desired time, and that produce high field and mill yields of good table quality.

In the Southern States the leading commercial varieties have fairly stiff straw and the field and mill yields on fertile land are relatively high, but there is an urgent need for greater disease resistance combined with improved table quality. In California, diseases are much less troublesome, but the early maturing varieties now grown in the State do not yield well except on virgin land or land that has not grown a rice crop for 2 or more years, and the milling quality of these varieties often is poor. Both the early and midseason varieties are likely to lodge when high yields are produced, and this often results in lower yields of inferior milling quality. There is therefore a demand for short-grain varieties having stiff straw, high yielding capacity, and better milling quality. There also is a demand by the rice growers and trade for medium-grain and long-grain varieties that can be successfully grown in California. Unfortunately, the varieties of these types now grown in the Southern States are not adapted to the California climate.

The elements involved in these desirable characteristics may be summed up as follows:

Yield depends on many factors. Among them, soil and climate—that is, environment—are important; for example, in California, land that has been fallowed 1 or 2 years normally produces from 500 to 1,000 pounds more per acre, when sown to the same variety, than similar land on which rice was grown the previous year. Yield is also decidedly affected by inheritance. Getting higher acre yields is the chief method by which cost of production can be reduced.

Good milling quality means that a lot or variety of rough rice, when milled, will give a high percentage of whole kernels. Short- and medium-grain varieties are normally of better milling quality than long-grain varieties, for the short- and medium-grain types are much less likely to be broken in the milling processes than are the long and long-slender grain types. In addition to the length and shape of the kernel, the stage of maturity, moisture content, hardness, depth of grooves on the kernels, method of handling, climatic and soil conditions, and other factors have a marked effect on milling quality.[6]

Table quality or culinary quality is a rather indefinite term that refers to the condition of the rice after it is cooked by boiling. Since the tastes of the people of various nations and within the nations differ, opinion as to what constitutes good table rice also differs. In the United States and Europe a good table rice is one in which the kernels retain their original shape when cooked by boiling, are not too sticky, and possess a desirable flavor.

THE PLANTS MUST BE SUITABLE FOR MACHINE HANDLING

Lodging, that is, bending over before or at maturity, is apparently due to many causes. It is not definitely associated with the size (diameter) of the culms or stems, for some varieties with small culms do not lodge, whereas others do. Varieties that have strong culms, regardless of size, do not lodge so readily. Those varieties in which the leaf sheaths tightly grip the culms are less inclined to lodge than varieties in which the culms are not tightly enclosed by the sheaths. The development of the root system, toughness of the culms, height of the plants, and weight of the panicles are factors which appear to be inherited and which determine to a certain extent whether a variety will or will not lodge readily. Lodging is also determined to some extent by the depth of seeding, manner of irrigation, time and manner of draining, and the fertility of the land. Varieties that lodge easily are unsuitable for commercial growing in the United States largely because the crop is harvested with rice binders or other machines. Often the loss in yield, because of lodging, is large, and the expense of harvesting is much higher than is the case for rice that stands up well when mature. Lodged rice is often poor in milling quality. In Asia, where labor is cheap and land expensive, lodging is not such a serious defect because lodged plants can be harvested by hand without much, if any, loss in yield.

Tillering refers to the number of stems produced from one seedling. The extent to which a variety tillers depends upon the thickness of seeding and the fertility of the land, and also on inheritance. Some varieties have a much greater capacity to produce tillers under a given set of conditions than others. In general, the late-maturing and midseason varieties tiller more freely than do the early-maturing varieties.

Shattering means that the grain falls off the panicles just before or at maturity because it is not held firmly. Varieties differ greatly with respect to the tightness with which the grain is held on the

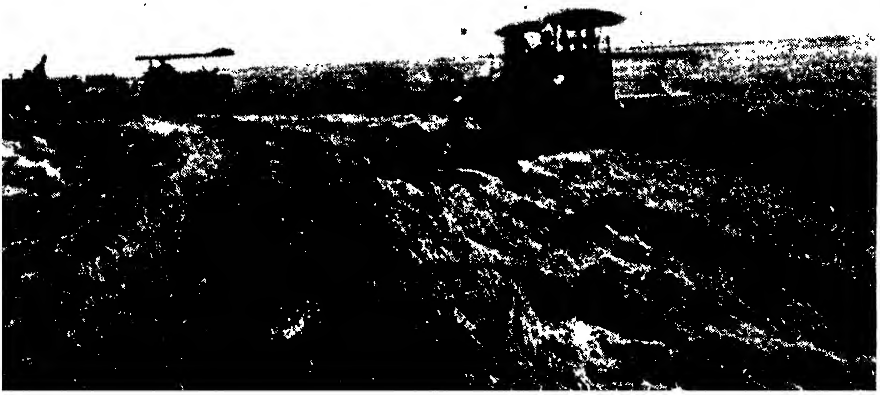
[6] The kernel of rice as it leaves the thresher is enclosed by a hard siliceous hull. Milling consists in cleaning the trash from this rough rice; removing the hulls, kernel coats, and germs; and polishing the kernels. The most valuable product obtained in milling is the whole kernel or head rice.

panicle. Those varieties that shatter readily are unsuitable for commercial growing in this country because the loss of grain before and during harvesting with machinery is excessive. However, the loss may not be high when harvesting is carefully done by hand. Shattering has been found to be a heritable character in rice.

Earliness varies greatly. The commercial varieties grown in the United States range in maturity from about 120 to 175 days. In the Southern States and in California there is a demand for early-maturing varieties of high yielding capacity and good milling and table quality. The principal value of early-maturing varieties is that they make it possible to harvest over a longer period, which means lower harvesting costs. In California, early varieties also are less likely to be damaged by unfavorable harvesting weather late in the season.

The diseases that are the most serious in the Southern States are leaf and glume spots, due largely to the fungus *Helminthosporium oryzae;* stem rot, due to the fungus *Leptosphaeria salvinii* Catt.; and seedling blight, due to the fungi *Fusarium* sp., *Rhizoctonia*, and *Ophiobolus miyabeanus*. These fungi cause considerable damage each year. Under unfavorable conditions for germination, seedling blight may bring a marked reduction in stands and probably in the resulting yields. Leaf spot often reduces the leaf area prior to maturity sufficiently to affect yield and quality. In severely affected fields, stem rot causes the plants to lodge before they are mature and hence reduces yields and results in inferior quality. Fortunately, varieties differ in susceptibility to these diseases. The nature of disease resistance has not been entirely solved, but sufficient data is available to indicate that in many cases it is a heritable character, and an effort is being made to develop disease-resistant varieties by hybridization.

FIGURE 5.—Binders drawn by tractors equipped with power take-off attachments harvesting rice in California.



Characteristics of Rice Varieties and the Work of the Breeder

THE rice plant, *Oryza sativa* L., is a member of the grass family, to which also belong wheat, corn, oats, barley, and grain sorghums. Rice normally is self-pollinated, but available information indicates that some natural crossing probably occurs in all rice-producing countries. The large number of cultivated varieties existing in the principal rice-producing countries of the Far East undoubtedly originated through natural crossing and as mutations. There are several wild species of rice in Asia, but all cultivated varieties of rice belong to the same species.

FIGURE 6.—A combine with a pick-up attachment threshing rice from the swath in California.

In India some 8,000 varietal names are known. In the Philippine Islands 3,500 varietal names have been recorded, and in Japan, Indochina, Java, and Malaya a large number of native varieties are grown. In the rice-producing countries of Europe and of North America, Central America, and South America fewer varieties are grown.

All cultivated varieties of rice can be grouped roughly into upland and lowland types. Upland varieties are not irrigated and the land normally is not submerged by the seasonal rainfall which supplies the crop with moisture. Lowland varieties normally are submerged from 2 to 8 inches deep during the greater part of the growing season, and deep-water varieties are grown to some extent in India and Indochina on lowland that may be submerged with water varying in depth from 3 to 30 feet during part of the growing season. The ordinary lowland varieties are much more extensively grown than are upland varieties, and the latter are much more important than are the deep-water

varieties. In Asia rice is grown at sea level and at elevations as high as 7,500 feet, but none of the varieties can withstand freezing temperatures during growth.

Rice varieties are grouped as common and glutinous, depending on the nature of the starch deposited in the endosperm. Of the two groups the common is by far the most important, although a good deal of glutinous rice is produced in the Orient and used in the preparation of pastries and candylike confections which are commonly used during festivals.

FIGURE 7.—Harvesting rice by hand in Japan.

Rice varieties differ markedly in tillering and yielding capacity, in height, in shape, length, and width of leaves, in thickness of culms, in length of panicles and awns, in the strength of straw, and in tendency to shatter when ripe.[7]

From seeding to maturing, rice varieties vary from 80 to 220 days or more. Regardless of the date of seeding, some varieties require a fairly constant number of days to mature, whereas other varieties, when sown late, tend to flower and mature during a given day length.

[7] The vegetative organ of the rice plant, including the leaf blade and sheath, the ligule, the auricle and pulvinus, and the culm internodes and nodes may be colored with anthocyan pigments. Likewise, the outer glumes, the inner glumes, the apiculus, and the awns may be colored. The outer and inner glumes and the awns may be yellow or straw-colored, or red, brown, or purplish black. The outer glumes may be short (normal), about one-third as long as the inner glumes, or as long as or nearly as long as the inner glumes. At maturity the panicle in different varieties may be still enclosed in the sheath, partly exserted, or well exserted from the leaf sheath. The panicle may be open or compact in arrangement, erect or drooping, and it may vary greatly in length. The spikelets may be arranged on fairly long separate pedicils or they may occur in clusters. The spikelets of different varieties may be fully awned, partly awned, tip awned, or awnless.

With the latter varieties, by seeding late, maturity may be hastened by as much as 50 days, but yields also are reduced. Many tropical varieties, when grown in temperate regions, fail to head before frost owing apparently to the long days, whereas late-maturing varieties from subtropical and temperate regions when grown in the Tropics, head very early owing to the relatively short days.

The kernels of common rice may be translucent, semitranslucent, partly opaque, or entirely opaque. They may be hard, semihard, or soft, and they may be soft and mushy when boiled, or firm and attractive. The kernels vary in size.[8] In color the unmilled kernel may be white, amber, red, or purple. The kernels may be scented or nonscented. The scented rices, which have a flavor somewhat like that of pop corn, are reported to be preferred by the wealthy in certain countries.

FIGURE 8. Threshing rice in Japan with a cylinder foot-power machine.

There is at least one variety that produces two or more endosperms within the same pair of glumes, and others that are reported to survive in brackish water. Some varieties are resistant whereas others are susceptible to the various diseases that attack the rice plant.

In all cultivated varieties of *Oryza sativa* in which the chromosome number has been counted, as well as in most wild varieties of this species examined, the haploid chromosome number, that is, the number of chromosomes in the reproductive cells, is 12. It is interesting to know that such a wide range of variation in structural characters, physiological responses, kernel color, size, shape, texture, quality, etc., actually exist in a single species, all with the same number of chromosomes. Varieties within this species differ so

[8] The variation in length runs from about 3.5 to 8.0 mm, in breadth from about 1.7 to over 3 mm, and in thickness from about 1.3 to 2.3 mm.

completely that when crossed the F_1 plant may be almost or completely sterile.

The various types and varieties of rice that have appeared and persisted through the ages represent to a certain extent the survival of the fittest, and some of these varieties possess desirable characters which can be used to advantage in breeding work. Before native varieties are discarded, it should be definitely determined that they do not possess any desirable qualities from a breeding standpoint.

Since the commercial varieties now grown in this country were isolated from varieties introduced largely from Japan and the Philippine Islands, it would seem advisable for breeders to focus their attention on the possibility of obtaining superior types from these countries. At present the United States Department of Agriculture, in cooperation with the State agricultural experiment stations, is maintaining viable seed of many varieties from different parts of the world for use in breeding work.

Owing to differences in climatic conditions and methods of production, only a few of the thousands of varieties introduced into this country have been found to be of commercial value. While many of the varieties that have been introduced tiller freely and produce high yields of good quality, often they mature too late and shatter and lodge too easily to be harvested with machinery. However, such varieties are valuable as breeding material for one or another desired characteristic, including resistance to disease.

METHODS AND RESULTS OF BREEDING

As with other small grains, three methods of improvement are used in breeding rice: (1) The introduction of varieties from foreign countries, (2) the isolation of pure-line selections from commercial and introduced varieties, and (3) the creation of new varieties by crossing followed by selection. Most of the improvements so far made in the United States have been accomplished by introduction and selection.

Introductions

Through the introduction of seed, the breeder can obtain varieties that have been developed by others, or that are native to older rice-producing countries. Introductions are grown in the greenhouse the first year, in order to be certain that new diseases are not brought into the rice area. In the second year the varieties are grown at one of the rice substations in 8-foot or rod rows spaced 1 foot apart. Careful notes are taken regarding the principal characteristics of the varieties, and whether they are breeding true or consist of mechanical or hybrid mixtures. Pure-breeding varieties that lack vigor or have other undesirable characteristics are discarded. In due time the introductions that show promise are advanced to the nursery yield tests. Here they are grown in replicated—that is, repeated—3-rod row plots for comparison with the standard commercial varieties. If the introductions are found to be more productive than the standard varieties, or if they possess other desired characters, they are distributed to farmers for growing on a commercial scale.

Apparently few or no rice varieties were introduced into the United States for testing during the period from about 1685 to 1889. The

growers seem to have been satisfied with the yields and quality of Carolina White and Carolina Gold, which were extensively grown during this period.

About 1890 the Honduras variety was introduced into Louisiana from Honduras through commercial sources. In 1899 S. A. Knapp, of the United States Department of Agriculture, made a trip to Japan to obtain varieties better suited for growing in the Southern States. Knapp, probably the first agricultural explorer of the Department of Agriculture, was responsible for the introduction of the Kiushu and Shinriki varieties. During the next 30 years several thousand varieties were introduced, mainly by the United States Department of Agriculture. These new introductions were tested largely in the cooperative experiments at the Rice Experiment Station, Crowley, La., and at the Biggs Rice Field Station, Biggs, Calif.

Of the thousands of varieties introduced from practically all the principal rice-producing countries of the world only a few have been found to be well adapted to the climatic conditions prevailing in the rice areas and the methods of production used in this country.

The sources of the more important introduced varieties that have been grown and those that are now grown on a commercial scale in the United States, with brief remarks concerning each, are given in the appendix (p. 442).

Selection

The plant- or panicle-selection method is used in isolating the best strains from commercial varieties and introductions that may consist of a mixture, whether naturally hybrid or due to mechanical mixing of seeds. A relatively large number of selections are made from promising varieties that show distinct variations. These selections are grown the first year in short rows spaced 1 foot apart, and the inferior lines, as identified by inspection, are discarded. Those that are promising are more extensively tested in replicated yield plots with rows a rod long. The lower yielding lines and those possessing such undesirable characteristics as poor grain quality, weak straw, shattering, etc., are discarded, and the yield tests are continued with only the better lines. Finally, the selections that appear to possess the qualities desired are tested for yield in replicated field plots in comparison with the standard commercial varieties, and later the best selections are distributed for commercial growing.

After Knapp's introductions from Japan, Haven Metcalf of the South Carolina Agricultural Experiment Station, H. R. Fulton of the Louisiana Agricultural Experiment Station, and G. H. Godfrey and W. H. Tisdale of the United States Department of Agriculture conducted studies on rice diseases. In 1908 Charles E. Chambliss, in 1909 J. Mitchell Jenkins, and in 1912 Ernest L. Adams, all of the Department of Agriculture, started varietal improvement work with rice in Louisiana and California. Later J. W. Jones, also of the Department of Agriculture, was active in this work. In 1907 the late S. L. Wright, an independent breeder of Crowley, La., began selection work with rice, and the more important varieties now grown in the Southern States were selected and distributed by him.[9] Roughly, 73 percent of the rice produced in the United States in 1934 consisted

[9] There are no active independent rice breeders in the United States at present.

FIGURE 9.—Pulling rice seedlings for transplanting in Japan

of varieties developed by S. L. Wright, and 27 percent consisted largely of varieties developed by the Department of Agriculture in cooperation with the Louisiana and California Agricultural Experiment Stations.

The sources and a brief description of the leading commercial varieties developed by selection are given in the appendix material. In table 1 (p. 445) are shown the acreage, estimated yield per acre, total yield, and percentage of the crop for the principal varieties grown in Louisiana, Texas, Arkansas, and California in 1934. Table 2 (p 447) gives information on varieties that have been grown and are now grown in this country, including an estimate of their points of superiority.

Hybridization

The improvement of commercial rice varieties by pure-line selection is a comparatively simple task, though a number of years are required to do the work. It is not so simple, however, to create new forms by crossing. The parents of the initial cross should possess the characters which the breeder desires to combine in one variety. However, even with promising parents, the desired genes may be linked with others so that few or none of the offspring will contain the combination wanted, whereas less promising parents when crossed may give desirable offspring. It now appears that the possibility of obtaining the combination of characters desired is materially enhanced by working with a relatively large number of crosses.

The technique of making a cross in rice varies more or less in different countries. The method now largely used in the hybridization of rice in the United States is as follows.

Usually in the morning before the rice begins to bloom, or less often in the afternoon after the daily blooming period has passed, all except 10 to 20 spikelets are removed from the female panicle.[10] The glumes on the remaining spikelets are clipped off at an angle of about 45°. This removes about half of the upper part of the lemma, but only the end and sometimes none of the palea. By clipping the glumes in this manner, all six anthers are exposed. They can be easily removed with a pair of fine-pointed forceps, often in one operation.

Technique Used in Making a Cross

In removing the anthers, it is best to begin with the upper spikelet, proceeding in order to the lower spikelets of the panicle. Thus there is less likelihood of pollen falling into an open flower below. After the anthers are removed, the emasculated panicles are tagged and bagged in the manner usual for cereal plants. The same day or the following day, between 10 a. m. and 2 p. m., the male panicles are examined, and a few panicles on which the anthers are pushed well up toward the apex or the tip of the glumes are collected. The position of the anthers can readily be seen by looking at them toward the sun. The glumes of the spikelets in which the anthers are well developed are gently pulled apart and one or more anthers are taken and placed in the emasculated female floret.

It is often necessary to break the anthers open to insure that the stigmas are well covered with pollen. This can be determined with a hand lens. Well-developed anthers may lose some pollen as soon as the glumes are pulled apart and the anthers are exposed to the air. Such anthers are ideal for use in cross-pollination, and often several florets can be pollinated with a single anther when it is in this

[10] Botanical terms used in this and the following paragraphs: Panicle, an inflorescence with a main axis and subdivided branches; spikelet, the unit of the inflorescence consisting of two glumes and one floret; lemma, the bract of a spikelet above the pair of glumes; palea, the inner bract of a floret; glumes, the pair of bracts at the base of a spikelet; floret, the lemma and palea with included flower (stamens and pistils); anther, the part of the stamen that contains the pollen; stigma, the part of the pistil that receives the pollen.

FIGURE 10.—Transplanting rice in Japan.

FIGURE 11.—Nursery at Rice Experiment Station, Crowley, La.

condition. Sometimes, however, several panicles are required to obtain sufficient pollen to pollinate 10 to 20 florets, owing to the fact that at any one time the anthers of only a small percentage of the spikelets are in the proper stage of development. If immature pollen is used, fertilization does not take place. After pollen has been placed on the stigmas of the emasculated florets, the panicles are again bagged and the bags are left on until the hybrid seed is mature.

The F_1 generation is grown so that each plant has ample space for full development. By a knowledge of the inheritance of the characters involved—that is, what characters are dominant—those plants which are not crosses are eliminated in F_1. The F_2 generation of each cross should include as many plants, space sown, as it is possible to study. A large number of plants having desirable agronomic and grain characters should be selected in F_2 for growing in the F_3 generation. Selection of desirable plants should continue in the F_3 and later generations. When desirable true-breeding lines have been isolated they are tested for yield in the replicated rod-row plots in comparison with standard varieties.

The progeny from crosses may also be grown in a bulk plot for several generations. In from 5 to 10 years panicle selections can then be made from the bulk plot, and many of these selections should breed true. This method has the advantage that many types unadapted to the environment are automatically eliminated during the period when the material is grown in the bulk plot. In California, for example, late-maturing segregates are automatically eliminated because of the relatively short growing season. This method can be used to advantage at stations where space for growing hybrid material is limited, or when other work requires most of the investigator's time.

A Method That Promises Fruitful Results

In 1922 the improvement of rice by hybridization was started by J. W. Jones at the Biggs (Calif.) Rice Field Station, and at present this method is being used in the cooperative rice-improvement work in each of the principal rice-producing States. The method promises to give fruitful results, but to date only one variety produced by hybridization is ready for commercial growing. A description of this variety, the Calady, is given in the appendix (p. 444).

There is no apparent reason why it should not be possible by hybridization to develop varieties that possess all, or nearly all, the important characters that are desired by producers, millers, and consumers. In California the Department is now testing the yield of a number of promising short-, medium-, and long-grain selections isolated from crosses made several years ago. Most of these selections have stiff straw, do not shatter, mature at a desirable time for harvesting, and yield well. In Arkansas, Louisiana, and Texas some promising selections have been isolated from crosses made in California in 1928 and 1929, and desirable strains also are being isolated from crosses made more recently at the southern rice stations.

Of the many varieties maintained in the collections of the Department of Agriculture and the State experiment stations, a few that are of no commercial value possess desirable characters from a breeding standpoint. This is notably the case with Bozu, a variety that matures very early; Butte, a variety that does not shatter; Aikoku and Kameji, which are fairly resistant to most of the rice diseases occurring in the southern rice area (this is also true of Butte); and "Kiniristol" C. I. No. 4700 and Kumbi C. I. No. 7143, which are very resistant to the leaf spot disease.

Some Results of Rice Breeding in Other Countries

RICE-IMPROVEMENT work in the principal producing countries of the world has been in progress for many years. Historically, it is often mentioned as the first crop that was improved by breeding. But in most countries well-organized programs were not started before 1900. Since many of the countries that produce the most rice consume practically all of it at home, the early efforts were to improve only the yielding capacity. British India (Burma), Indochina, and Siam, which are exporting countries, are now emphasizing improvement in quality as well as yield, so that their product may be better able to compete in the world markets with rice from Italy, Spain, the United States, and other temperate regions.

The methods followed abroad are the same as those already described for the United States.

In most of the principal rice-producing countries of Asia and the nearby islands, the native varieties have been collected and classified, and the yielding capacity of many of them has been tested. Pure-line selections have been isolated from the most promising varieties

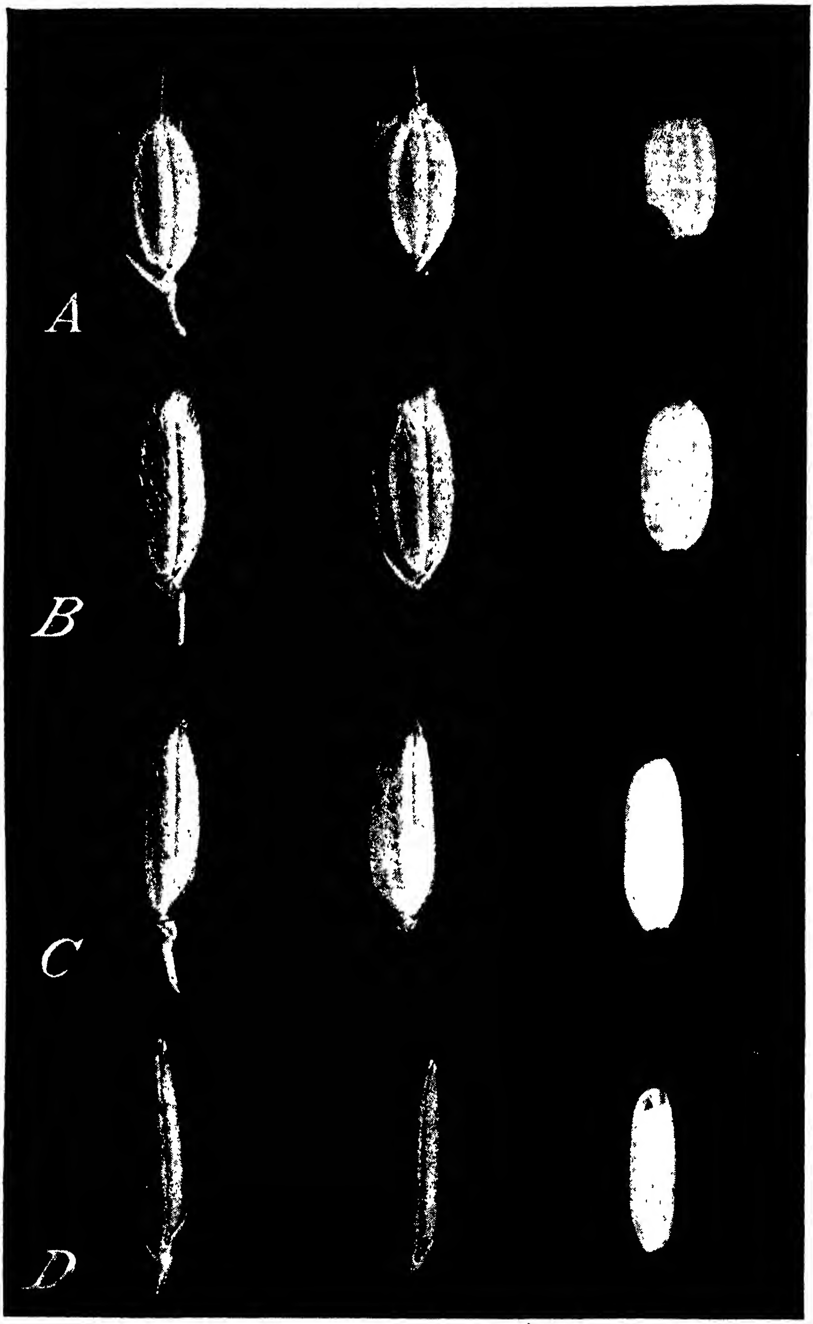


FIGURE 12.—Spikelet, seed, and kernel of (*A*) Caloro, short-grain; (*B*) Blue Rose, medium-grain; (*C*) Fortuna, long-grain; and (D) Rexoro, long-slender-grain rice.

and the best of these selections have been distributed to growers. In the Far East the introduction of varieties from abroad has not been nearly so effective a means of improvement as in the countries located in temperate regions.

Hybridization is a comparatively recent development, and with the possible exception of Japan, few of the commercial varieties now grown were developed in this manner, but it is to be expected that the method will be developed much more fully. In the countries that have more or less exhausted the possibilities of improvement by selection and introduction, breeders are concentrating on hybridization. In many countries that have numerous native varieties, however, selection still is the method emphasized, for it is most likely to result in a marked increase in yield in a relatively short period of time.

In practically all rice-producing countries the national department of agriculture cooperates with the state, provincial, prefectural, district, and other agencies in carrying on the rice-improvement work. An attempt is made by the central government agencies to coordinate the rice-research program, to provide funds and equipment, to encourage the exchange of material and ideas, and to undertake work that is of regional importance.

Practically all the large rice-producing countries have developed selection and seed-testing farms in the principal rice areas. Such farms are common in India, Java, Ceylon, Malaya, Indochina, and Japan. In Japan the prefectural experiment stations also serve much the same purpose, and in addition are carrying on regular research programs. Two conditions are largely responsible for the development of the seed farms—(1) the uncertainty regarding the yielding capacity of improved varieties when grown under conditions different from those under which they were developed, and (2) the difficulty experienced in distributing the improved varieties to producers, and in maintaining suitable clean seed supplies of the improved types.

The acreage sown to rice in the Far East is so large, the environmental conditions under which the crop is grown are so varied, and the methods of production are so diverse that innumerable varieties are needed differing in date of maturity, moisture requirements, and other physiological responses. In the following brief summary, therefore, no attempt is made to list the large number of improved varieties that have been developed. Such a list would be of no value unless the conditions under which the varieties are grown could be given also.

The appendix (p. 453) gives the institutions and stations located in the principal rice-producing countries of the world at which rice-improvement work is being conducted, or from which information on rice improvement may be obtained.[11]

INDIA

The area sown to rice in India in 1930–31 was 82,428,000 acres, of which about 1,287,000 was in improved varieties distributed by research agencies of the Imperial Government and various local governments. The improved varieties are said to be more productive,

[11] A list of institutions and stations is likely to be of more service than the names of individual workers connected with such institutions because changes in personnel occur quite frequently.

superior in quality, more resistant to diseases, lodging, and shattering, more uniform in maturity, or maturing at more desirable periods for harvesting. Many improved varieties are available for growing in the particular areas where they were developed. Most of the improved varieties were obtained by selection, and they are said to yield from 5 to 25 percent more than unselected varieties. In India proper the average yield of rough rice was 1,215 pounds per acre in 1933–34.

CHINA

The National Research Bureau of Agriculture is carrying on tests to determine the regional adaptation and limitation of important Chinese rice varieties. Native varieties are being subjected to selection with the object of isolating strains with superior yielding capacity and disease and insect resistance. Varieties are being introduced from foreign countries, and at some of the institutions hybridization work also is under way. A few promising selections have been isolated and are being distributed for commercial growing, but most of the rice area is still sown to native varieties that have demonstrated their value for various regions.

JAPAN

Terao[12] states:

> * * * the annual production of rice in Japan Proper (exclusive of Korea and Formosa) has been elevated for the last thirty-five years by fifty-six per cent; this is due, on one hand, to an extension of paddy fields by sixteen per cent and, on the other hand, to an increase of the average yield per unit of thirty-five per cent. * * * There exist two important lines of technical improvement which have really proved most effective for increasing yields throughout the country, namely, the liberal use of fertilizers and the improvement of rice strains.

Through cooperation of the Imperial and prefectural experiment stations, the rice strains cultivated in Japan have passed through various stages of improvement. (1) The numerous local varieties in each prefecture were included in varietal tests, and those best suited to each locality were selected to replace inferior strains. (2) Since 1916 the selected local varieties mentioned above were again subjected to pure-line selection at all the prefectural stations.

Until recently, hybridization of rice has been conducted largely at the Imperial agricultural experiment stations. Since 1927, however, an important extension has been made, especially of rice hybridization, the work being organized at certain prefectural experiment stations which represent different climatic sections of the country. A similar system is now in operation with upland rice. The distribution of improved seed also has been systematically carried out by establishing a network of seed-propagation farms covering the whole country. In Japan proper the average acre yield of rough rice in 1933–34 was 3,735 pounds.

Taiwan

After 20 years' work, Japanese varieties under the trade name of the Horai varieties have been acclimatized to Taiwan (Formosa). In 1922 the Horai varieties were grown on 400 cho (2.45 acres) and in 1932 on 147,000 cho or 22.5 percent of the total area sown to rice in Taiwan. They produced in 1932, 1,909,000 koku (5.12 bushels) or 25.5

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[12] TERAO, H. ON THE IMPROVEMENT OF THE TECHNIQUE OF RICE CULTIVATION IN JAPAN. 4th Pacific Sci. Cong. Proc. 4: 253–256. 1930.

percent of the total rice crop. Two rice crops a year are grown in Taiwan. In 1934 the Horai varieties constituted more than 61 percent and in 1935 more than 65 percent of the total first crop produced in those years. The surplus rice produced in Taiwan is exported to Japan, and since Japanese prefer the Japanese types of rice, the breeding of the Horai varieties is an important achievement, for the surplus has a ready market in Japan.

Chosen

In recent years considerable improvement in the yield of rice in Chosen (Korea) has been attained, largely by the improvement of irrigation facilities, methods of culture, and the use of improved varieties. Improved varieties from Japan have been introduced and tested, and those found to be adapted have been distributed for commercial growing. Improved Japanese varieties have largely replaced native varieties in the better developed rice areas of central and southern Chosen, and to a smaller extent in other sections. It has been estimated that over 70 percent of the area sown to rice in Chosen consists of improved Japanese and Korean varieties.

INDOCHINA

In Indochina, seed of improved varieties, developed by mass and pure-line selection methods, has been distributed—among them, a few years ago, Huêky and Ramai. Information on the extent to which improved varieties are grown is not available. It is stated, however, that the rice-breeding work has resulted in an increase in production per acre.

DUTCH EAST INDIES

Selection work with rice in the Dutch East Indies began in 1905. By 1915 no beneficial results had been obtained. The failure to obtain desirable results was attributed to the fact that the lines used were probably not homozygous. It was determined that selected lines had a narrower range of adaptability than unselected varieties. Since 1922 a method of inbreeding by bagging or spacing the plants far enough apart to insure self-pollination has been used, and in several instances strains have been obtained that produced up to 25 percent more than the unselected varieties. About 9,000,000 acres are sown to rice in the Dutch East Indies, and it is estimated that improved varieties are grown on about 250,000 acres.

MALAYA

In Malaya high-yielding pure-line selections have been isolated from the principal native varieties. Several of these have been released for growing by farmers, and the acreage sown to the improved varieties is said to have increased quite rapidly.

PHILIPPINE ISLANDS

Rice-improvement work in the Philippines was started in 1914. Native varieties, which are numerous, have been collected, and mass and individual selections have been made from the more important

commercial varieties and types. Improved varieties that have been distributed and are grown quite extensively include Apostol and Guinangang, which mature early and produce high yields; Elon-elon, a variety of good quality which is the principal one grown for export; and Ramai, which was introduced originally from Indochina and is probably the highest yielding variety grown in the Philippines.

CEYLON

In Ceylon emphasis has been placed on the problem of selecting high-yielding, stiff-strawed, awnless strains from the varieties grown on a large scale. A number of pedigree selections, chosen almost entirely for high yields, have been distributed and have attained wide popularity. The most popular include Vellai illankalayan (Selection 28061), Perillanel (Selection 26014), Sudu hinati (Selection Hf. 9), and Pachchaiperunae (Selection 2462/11). Over 90 percent of the Ceylon rice varieties have red grains.

ITALY

The yield of rice in Italy has increased from 2,306 pounds per acre in 1901 to 4,381 pounds in 1929. This remarkable increase in yield has been due to several factors, including the more general use of improved cultural practices, a more extensive use of fertilizers, systematic rotation, the practice of transplanting part of the acreage, and the use of improved varieties obtained by introduction and selection.

Colusa, introduced from California, and Sancio, Roncarolo, and Maratelli, selected from Chinese Originario, are grown on a commercial scale, as well as several other introduced and selected strains. Based on quality, the varieties grown in Italy are grouped as follows: Ordinary quality: Chinese Originario, American 1600, Onsen, Sancio, Sekiyama, Precoce Giallo Ardizzone, Precoce Vittoria, Roncarolo, Benloch; quality fairly good: Precoce Novella, Precoce Allorio, Lencino, Ranghino, Greppi, Maratelli, Precoce 6, Precoce Dalloraloe, Chinese Ostiglia, Precoce Americano; quality good: Settala, Nero di Vialone, Ostiglia, Bertone.

SPAIN

The average acre yield of rice in Spain is much higher than that in any other important rice-producing country. The average yield of rough rice exceeds 5,000 pounds per acre. The rice fields are small and well cultivated, fertilizers are commonly used, and the rice is transplanted. The principal varieties grown include Bomba, Amonquila, Chinese Originario, Benloch, and Colusa. Varieties from Japan and Italy do well in Spain, and the introduction of improved varieties from these countries has been of material benefit to the rice industry.

EGYPT

The Ministry of Agriculture in Egypt has been carrying on investigations in rice improvement for several years. Local and introduced varieties have been tested and the more promising have been subjected to pure-line selection. In 1930 seeds of the following selected strains were available for distribution to rice growers: Yabani 2,

New Yabani 6, Nabatat 1, Nabatat 2, and Fino 9. The improved variety Yabani 15 was grown on about 30,000 acres in 1935.

AUSTRALIA

The plant-breeding branch of the Department of Agriculture of New South Wales started a rice-improvement program in 1927. Mass and pure-line selection, introduction of varieties from other countries, and hybridization methods are being used. Three selections have been increased and distributed to farmers—Caloro II, Late Caloro (8 to 10 days later than Caloro), and Colusa 180.

BRITISH GUIANA

The Department of Agriculture of British Guiana has conducted a breeding program with rice for several years. Local varieties, introduced varieties, and pure-line selections have been tested. Pure-line seed of Blue Stick and Demarara Creole, and Selection No. 79, have been distributed by the Department of Agriculture through seed farms. In 1931 hybridization was started with the following objectives: High yield, stiff straw, good quality, and early maturity.

The Progress of Genetic Research with Rice

SHORTLY after the rediscovery of Mendel's law of heredity in 1900, studies on the inheritance of characters in rice were begun. The mode of inheritance of easily identified characters was naturally the first to be determined, and during the last 25 years many papers have been published dealing with genetic studies in rice. The pioneers in this work include Van der Stok in Java; Okada, Kato, Ikeno, and Hoshino in Japan; Hector and Parnell in India; and more recently, Jones and Chao in the United States.

The mode of inheritance of a relatively large number of individual characters has been determined, as will be evident from a glance at table 3 (p. 450), which gives the principal characters studied, the ratios obtained in F_2, and the names of those who did the work.[13] In spite of the large number of characters studied, few cases of linkage—that is, the location of different genes in the same chromosome—have been definitely demonstrated. This is probably owing to the fact that the characters have largely been studied independently.

A gene S for reddish apiculus color and a gene M for starchy endosperm were reported by Yamaguti in 1921, and later, to be linked, with about 20 to 22 percent of crossing over. In 1927 and later the same author found that a gene F_1 for heading time was also linked with S and M. Crossing over between F_1 and M in four cases was

[13] In preparing table 3, an effort was made to give credit to the first investigator to report on a given character, but probably this has not always been done. The inheritance of the same character has often been studied by several investigators, and not all of them are listed in the table. For a more detailed list of the men who have contributed to the knowledge of rice genetics, the reader is referred to the following publication: MATSUURA, H., A BIBLIOGRAPHICAL MONOGRAPH ON PLANT GENETICS (GENIC ANALYSIS), 1900–1929. Ed. 2. rev. and enl., 787 pp., illus. Sapporo, Japan.

24, 15, 8.8, and 13.6 percent, respectively. A gene T_v for tawny awn, apiculus, and outer glume color also was reported by Chao (1928) to belong to this group. Crossing over between T_v and M was calculated as 16.59 percent.

A gene R_1 for red grain was reported by Yamaguti (1929) to be linked with one of the genes Fx for heading time, with 22 percent of crossing over.

A gene for dark gold glume color was reported by Parnell and others (1927) to be linked with a gene L for purple lining of the internode, and later Yamaguti (1927) calculated the crossing over as 16.6 percent.

Hector (1922) reported that a gene for colored ligule is linked with a gene for colored glume with 12.5 percent of crossing over.

FIGURE 13.—J. Mitchell Jenkins, Rice Experiment Station, Crowley, La.

Nagai (1926) reported a gene n for staminodal sterility is completely linked with a gene g for paleaceous sterility.

Chao (1928) reported that a gene Sp for spikelet length is linked with one of the duplicate genes G_2 for empty glume length, with 1.11 percent of crossing over; that a complementary gene Sa_2 for stigma color is linked with one of the complementary genes Ls_2 for leaf sheath color, with 9.8 percent of crossing over; and that a gene Pr_2 for purple kernel color is closely linked or identical with one of the complementary genes Lg_3 for ligule color.

Color in two or more plant organs has been found in several cases to be inherited as if it were due to the same gene or genes or to closely or completely linked genes. In future genetic studies with rice, emphasis should be placed on the problem of determining the linkage relationships of the genes that are responsible for individual characters.

Some work has been done in making crosses between different species of rice, with meager results so far.[14]

Unusual Chromosome Numbers

As already noted, the haploid chromosome number in all the cultivated rice varieties and variants examined up to 1931 is 12. That is, all these varieties proved to have 12 chromosomes in the reproductive

[14] Gotoh and Okura report that the somatic chromosome number of the wild species, *Oryza cubensis* Ekman and *O. latifolia* Desv., both from Cuba, is 24 and 48, respectively. In 1933 the writer crossed Colusa, a cultivated variety of *O. sativa* and *O. cubensis*. One F_1 plant was grown in the greenhouse in the season of 1934 and it was sterile. In the spring of 1935 the F_1 plant was subdivided at the crown into several plants, some of which were again grown in a greenhouse, while others were grown in the field nursery at Texas Substation No. 4, Beaumont, Tex. These F_1 plants so far have been sterile. Ramiah, in 1934, reports that after repeated attempts, a cross was obtained between a cultivated variety of *O. sativa* and *O. latifolia*, and infers that the F_1 plant was sterile. The tall annual grass known in the United States as wild rice (*Zizania aquatica* L.), is only distantly related to cultivated rice.

cells, which would give 24 in the somatic or body cells, when two reproductive cells combine.

In 1931 Morinaga and Fukushima reported the finding of a haploid rice plant in some F_1 progenies, that is, a plant with only 12 chromosomes in its body cells. This seems to be the first rice plant ever examined that had less than 24 chromosomes in the somatic cells.

An abnormal plant which proved to be a triploid (three sets instead of two sets of chromosomes in the body cells) was reported by Nakamori in 1932, and in 1933 he found three abnormal plants in hybrid progenies which also proved to be triploids. As compared with normal plants, the triploid plants had broader leaves, thicker stems, and longer spikelets, and they were partly sterile.

Nakamori states that in 1934 he found a tetraploid rice plant (four sets of chromosomes in the body cells) in some F_1 progenies. This plant also was partly sterile and had large spikelets with strongly developed awns.

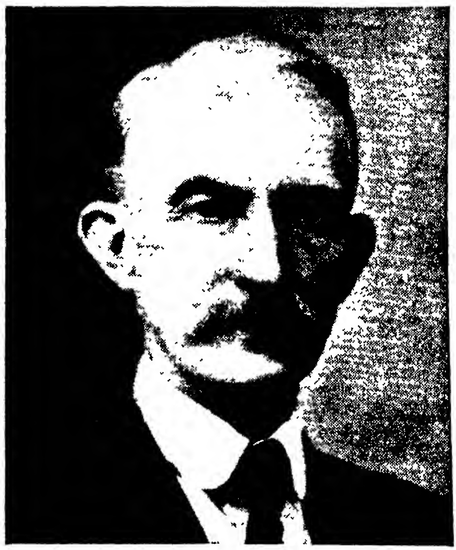

FIGURE 14.—The late Salmon L. (Sol) Wright, Crowley, La. Born April 26, 1852, Auburn, Ind.; died February 10, 1929.

Normally the kernel of rice has a single germ which produces one seedling upon germination. Occasionally, however, rice kernels are found that have two germs, and when such a kernel germinates twin seedlings are produced. In 1932, in a study of twin seedlings, Ramiah found that in all cases except one the twins were essentially identical in all respects. In the exceptional case, one of the twins was normal whereas the other was slightly dwarfed, the panicles did not emerge well, the spikelets were smaller than those of the sister plant, and the plant was entirely sterile. Upon cytological examination, it was found to be a haploid—12 chromosomes in the somatic cells.

Ichijima in 1934 reported on studies made on the possibility of artificially inducing mutations in rice by means of X-ray, ultraviolet ray, and variations in temperature. Various types of mutations were obtained in the F_1 generation, covering all those reported as occurring spontaneously, such as dwarf and miniature types, short panicles with dense spikelets, variegated and albino leaves, short and broad leaves, twisted and drooping leaves, sterility of various degrees, and early ripening strains. In the cytological examination of 19 plants with abnormal characteristics, 2 proved to be heteroploids (2 sets plus 1 extra chromosome in the body cells, or 25 in all), six were triploids and one was a tetraploid.

Appendix

Sources and Characteristics of Leading Commercial Varieties of Rice in the United States

Introductions

(1) *Carolina White.*—Carolina White was introduced by chance into South Carolina in 1694, presumably from Madagascar. It was well adapted for production on the delta lands of the South Atlantic States. Carolina White is an early-maturing long-grain rice of good table quality. It has a relatively stiff straw but is susceptible to diseases.

(2) *Carolina Gold.*—Carolina Gold probably came in as a mixture in Carolina White and later was isolated and grown as a separate variety. However, it may have been a later introduction. Carolina Gold is a long-grain rice that matures slightly later than Carolina White. The straw is stiff and the kernel is enclosed by a gold-colored hull. Carolina White and Carolina Gold are rices of excellent table quality and they became rather famous in the clean-rice markets of Europe. These two varieties were extensively grown on the delta lands of the South Atlantic States for a period of nearly 200 years.

(3) *Honduras.*—The Honduras variety was introduced from Honduras by commercial agencies about 1890. Owing to its productiveness, Honduras soon replaced the Carolina varieties on the delta lands of Louisiana. Honduras was the leading variety grown on the prairie lands of Louisiana, Texas, and Arkansas as long as virgin land was available for rice production. Honduras is a stiff-strawed, early-maturing, long-grain rice of good table quality. It was replaced in the Southern States largely by the early-maturing long-grain varieties Edith and Lady Wright, which were selected and distributed by S. L. Wright.

(4) *Kiushu.*—Kiushu was introduced from Japan by S. A. Knapp of the United States Department of Agriculture in 1899. It was a short-grain rice that is reported to have produced high field and mill yields in the southern rice area. It was soon replaced by Shinriki and other short-grain varieties also introduced from Japan.

(5) *Shinriki.*—Shinriki was introduced from Japan by S. A. Knapp of the United States Department of Agriculture in 1902. It is a late-maturing, stiff-strawed, short-grain rice that tillers freely and produces high field and mill yields of good quality. This variety was rather extensively grown in Louisiana and Texas until about 1910. Various strains of Shinriki are still extensively grown in Japan.

(6) *Wataribune.*—The Wataribune variety was first introduced from Japan in 1908 by S. Sabaira, a Japanese grower, of Webster, Tex. Later this variety was also introduced by the United States Department of Agriculture. Wataribune is a late-maturing, short-grain rice that tillers freely and produces high field and mill yields of good quality. It was never grown extensively in Louisiana and Texas but was the leading variety grown in California from 1912, when the first commercial crop was produced, until 1918.

(7) *Omachi.*—Omachi was introduced from Japan in 1910 by a rice grower of Crowley, La. It is a late-maturing, short-grain rice very similar in growth, yield, and quality to Wataribune. In this country Omachi has not been of nearly so much commercial value as has Wataribune.

(8) *Early Wataribune.*—Early Wataribune was introduced from Japan in 1913 by W. K. Brown, of the Moulton Ranch, Butte City, Calif. Early Wataribune is a midseason, short-grain variety that tillers freely and in California produces relatively high field and mill yields of good quality. It matures about 10 days earlier than Wataribune and for this reason largely replaced Wataribune in California. Early Wataribune is still grown on a small acreage in California.

(9) *Onsen.*—Onsen is an early-maturing, short-grain rice, introduced from Japan in 1918 by a Japanese rice grower of Biggs, Calif. It matures a few days earlier than Colusa but lodges more easily and does not yield quite so well. It is still grown on a small acreage in California.

Selections

(1) *Blue Rose.*—The Blue Rose variety was developed by selection from an unknown variety, found by J. F. Shoemaker in 1907 growing in a field of Japanese rice near Jennings, La., by S. L. Wright of Crowley, La. Blue Rose was distributed to growers in the fall of 1911 and was first grown on a commercial scale in

1912. It has been and still is popular with the rice growers of the Southern States owing to the fact that it is vigorous, has a stiff straw, and yields and mills well. Blue Rose is a late-maturing, medium-grain variety. It is estimated that about 50 percent of the rice produced in the United States in 1934 consisted of Blue Rose. Blue Rose unfortunately is susceptible to certain diseases, and in table quality it might be improved. The Improved Blue Rose, Supreme Blue Rose, and Greater Blue Rose, which were also selected and distributed by S. L. Wright, are essentially the same as Blue Rose, and if grown on a commercial scale, all are known in the rice trade as Blue Rose.

(2) *Early Prolific.*—Early Prolific is an early-maturing, vigorous, medium-grain variety that was selected and eventually distributed in 1915 by S. L. Wright of Crowley, La. It produces relatively high field and fair mill yields but is markedly inferior in table quality to Blue Rose. Early Prolific is susceptible to diseases. It is estimated that in 1934 about 18 percent of the rice produced in the United States consisted of this variety. Improved Early Prolific, which also was selected and distributed by S. L. Wright, if grown commercially, is known as Early Prolific.

(3) *Caloro.*—A number of selections were made in 1913 from Early Wataribune by E. L. Adams, superintendent of the Biggs (Calif.) Rice Field Station, and Charles E. Chambliss of the United States Department of Agriculture. The highest yielding of these selections later was named Caloro and was distributed in the spring of 1921 by the writer, who then was superintendent of the Biggs Rice Field Station. Caloro is a midseason, short-grain variety that heads and matures uniformly and produces on virgin and old rice land relatively high field yields of fairly good milling quality. Caloro soon largely replaced Early Wataribune and has been for many years the leading commercial variety grown in California. It also yields well in Missouri, Arkansas, Louisiana, and Texas, and thus appears to be adapted for growing under a rather wide range of conditions. It is estimated that Caloro was grown on 75 percent of the area sown to rice in California in 1934. It also is grown to a limited extent in Arkansas and Texas. In 1934 about 23 percent of the rice produced in the United States consisted of the short-grain varieties, mostly Caloro.

(4) *Colusa.*—Colusa is a pure-line selection made in 1911 by Charles E. Chambliss and J. Mitchell Jenkins in the cooperative experiments at the Rice Experiment Station, Crowley, La., from Chinese, a variety introduced from Italy in 1909 by Haven Metcalf. Colusa was tested at the Biggs Rice Field Station (Calif), from 1913 to 1916. In 1917 Colusa was grown on about 200 acres and was further distributed by E. L. Adams of the Biggs Rice Field Station in 1918. Colusa is an early-maturing, short-grain variety that produces high field yields on fertile land. Colusa has been for many years and is still the most popular early-maturing variety grown in California. In 1934 it is estimated that Colusa was grown on 15 percent of the California acreage. Caloro and Colusa were grown on some 95,500 of the 106,000 acres sown to rice in California in 1934.

(5) *Lady Wright.*—Lady Wright is an early-maturing, long-grain variety that was selected and distributed in 1920 by S. L. Wright of Crowley, La. Lady Wright has a stiff straw, is vigorous, and produces higher field yields than Edith, but in quality it is said to be the poorest long-grain rice grown in the South. This variety, like Edith, is susceptible to diseases. It is estimated that 2.97 percent of the rice produced in the United States in 1934 consisted of Lady Wright.

(6) *Rexoro.*—Rexoro is a pure-line selection made in 1926 by Charles E. Chambliss and J. Mitchell Jenkins in the cooperative experiments at the Rice Experiment Station, Crowley, La., from the Marong-paroc variety, introduced by the United States Department of Agriculture in 1911 from the Philippine Islands. Rexoro is a late-maturing, long-slender-grain rice that yields and mills well for a variety of this type. The table quality of Rexoro is very good and it is also resistant to certain diseases. Rexoro was released by the Department in cooperation with the Louisiana Agricultural Experiment Station for commercial growing in 1928. The acreage sown to Rexoro in Louisiana and Texas has gradually increased. Rexoro rough rice has been selling for 35 cents per barrel more than Blue Rose and 75 cents per barrel more than Early Prolific. Owing to its late maturity, Rexoro is grown only in Louisiana and Texas, and in 1934 about 1.92 percent of the rice produced in the United States consisted of this variety. In 1935 the acreage sown to Rexoro was materially increased.

(7) *Fortuna and Texas Fortuna.*—Fortuna is a pure-line selection made in 1911 by Charles E. Chambliss and J. Mitchell Jenkins in the cooperative experiments at the Rice Experiment Station, Crowley, La., from the Pa Chaim variety, which was introduced by the United States Department of Agriculture from Taiwan (Formosa) in 1905. Fortuna is a late-maturing, long-grain rice that yields well

and mills fairly well. It is resistant to certain diseases and is of good table quality. Fortuna was released, by the Department in cooperation with the Louisiana Agricultural Experiment Station for commercial growing in 1918, but owing largely to the fact that it shatters slightly, the growers have not, until recently, fully appreciated its desirable characteristics. The acreage sown to Fortuna and Texas Fortuna in Louisiana and Texas has increased in recent years, and the rough rice of Fortuna has been selling for 30 cents per barrel more than Blue Rose and 70 cents per barrel more than Early Prolific. Fortuna is grown only in Louisiana and Texas, and in 1934 about 1.88 percent of the rice produced in the United States consisted of Fortuna and Texas Fortuna. Texas Fortuna was selected in 1912 from Pa Chaim and distributed in 1925 by the Texas Agricultural Substation No. 4, Beaumont, Tex. Fortuna and Texas Fortuna appear to be identical. The acreage sown to Fortuna was materially increased in 1935.

(8) *Edith.*—Edith is an early-maturing long-grain variety that was selected and finally distributed in the fall of 1916 by S. L. Wright of Crowley, La. Edith does not yield so well in the field or mill so well as Blue Rose and Early Prolific, but in table quality it is said to be superior to these varieties. Edith has a stiff straw, but owing to its relatively low field and mill yields on the prairies and its susceptibility to diseases, it is not extensively grown. Of the total rice produced in the United States in 1934 about 1.74 percent was Edith. The acreage sown to Edith has decreased in recent years.

(9) *Nira.*—Nira is a pure-line selection made in 1928 by Charles E. Chambliss and J. Mitchell Jenkins in the cooperative experiments at the Rice Experiment Station, Crowley, La., from a variety introduced by the United States Department of Agriculture in 1916 from the Philippine Islands. Nira was released for commercial growing in 1932 by the Department in cooperation with the Louisiana Agricultural Experiment Station. It is a late-maturing, long-slender-grain rice that yields and mills well. The kernel of Nira is more cylindrical than that of Fortuna and it appears to be of better milling quality. Nira is attracting the attention of producers and millers in Louisiana, Texas, and Arkansas, and the acreage sown to this variety was materially increased in 1935. In 1934 about 2,400 acres were sown to Nira in Louisiana and Texas, and it made up 0.27 percent of the total rice produced in the United States.

(10) *Shoemed.*—Shoemed is a pure-line selection made in 1928 by Charles E. Chambliss and J. Mitchell Jenkins in the cooperative experiments at the Rice Experiment Station, Crowley, La., from the Guinosgar variety, introduced by the United States Department of Agriculture in 1916 from the Philippine Islands. Shoemed was released by the Department in cooperation with the Louisiana Agricultural Experiment Station for commercial growing in 1932. It is an early-maturing, medium-grain variety that yields fairly well, shatters somewhat, and has not milled well. Even though it has a stiff straw and is of good quality, it was grown on only 222 acres in Louisiana and Texas in 1934.

Hybridization

The Calady rice variety was developed by selection from a cross made by Jenkin W. Jones in 1924 between Caloro, a short-grain, and Lady Wright, a long-grain variety, in the cooperative experiments at the Biggs Rice Field Station, Biggs, Calif. Seed from the cross Caloro × Lady Wright was grown from 1926 to 1928, inclusive, in a bulk plot. In 1928, panicle selections were made from this bulk population. From these selections one strain was isolated, tested for yield, increased, and named Calady.

Calady is a medium-grain rice. At maturity, the hull enclosing the kernel is light gold in color. The straw of Calady is stiffer than that of Caloro, and owing to this characteristic, the panicles, when ripe, are held more erect than those of Caloro. Calady matures at about the same time as Caloro. The kernels are likely to "check" if the crop stands in the field until fully ripe, and for that reason the variety should be harvested before the grain is fully mature. The kernels are slightly smaller and more slender than those of Blue Rose and are hard, clear, oily, and attractive in appearance.

Calady appears to be best adapted for growing on fairly rich soils or land that is fertilized. On poor land, the yields are relatively low, the variety stooling less on poor land than does Caloro.

In 1934, about 2,500 sacks of Calady were produced in California under the direction of the California Farm Bureau. Enough seed was distributed in California in the spring of 1935 to sow from 750 to 1,000 acres. Calady does not yield well in the Southern States.

TABLE 1.—*Acreage, estimated [1] yield per acre, total production, and percentage of the crop for the leading commercial rice varieties grown in Louisiana, Texas, Arkansas, and California, and the total acreage, production, and percentage of the crop for each variety grown in 1934*

Variety	C. I. no.	Louisiana: Acreage	Louisiana: Estimated yield per acre (bushels)	Louisiana: Total yield (bushels)	Louisiana: Percentage of crop
Blue Rose [2]	1962	312, 139	40. 0	12, 456, 796	81. 38
Early Prolific [3]	5883	38, 534	43. 9	1, 703, 880	11. 13
Caloro, Colusa [4]	1561-1	380	39. 2	14, 929	. 10
Lady Wright	5451	1, 285	26. 3	33, 905	. 22
Rexoro	1779	6, 283	40. 7	256, 363	1. 67
Fortuna	1344	13, 629	40. 0	545, 080	3. 56
Edith [5]	2127	4, 248	47. 5	201, 503	1. 32
Nira	2702	2, 080	41. 0	85, 709	. 56
Shoemed	3625	175	54. 0	9, 511	. 06
Estimated total		378, 753		15, 307, 676	100. 00
Actual total [6]		394, 000		15, 957, 000	

Variety	C. I. no.	Texas: Acreage	Texas: Estimated yield per acre (bushels)	Texas: Total yield (bushels)	Texas: Percentage of crop	Arkansas: Acreage	Arkansas: Estimated yield per acre (bushels)	Arkansas: Total yield (bushels)	Arkansas: Percentage of crop
Blue Rose [2]	1962	66, 683	49. 3	3, 293, 532	44. 67	62, 820	43. 6	2, 742, 898	44. 89
Early Prolific [3]	5883	41, 910	50. 0	2, 104, 675	28. 55	61, 820	46. 4	2, 875, 846	47. 07
Caloro, Colusa [4]	1561-1	6, 799	49. 0	332, 910	4. 52	2, 675	46. 1	123, 466	2. 02
Lady Wright	5451	17, 023	54. 7	936, 115	12. 70	2, 700	46. 4	126, 050	2. 06
Rexoro	1779	8, 500	52. 9	450, 799	4. 95				
Fortuna	1344	2, 564	58. 3	149, 951	3. 19				
Edith [5]	2127	2, 122	41. 4	87, 700	1. 19	4, 700	51. 1	241, 355	3. 96
Nira	2702	298	50. 4	15, 077	. 20				
Shoemed	3625	47	47 1	2, 232	. 03				
Estimated total		145, 947		7, 392, 991	100. 00	134, 715		6, 109, 615	100 00
Actual total [6]		146, 000		7, 738, 000		136, 000		6, 936, 000	

See footnotes at end of table.

TABLE 1.—*Acreage, estimated*[1] *yield per acre, total production, and percentage of the crop for the leading commercial rice varieties grown in Louisiana, Texas, Arkansas, and California, and the total acreage, production, and percentage of the crop for each variety grown in 1934*—Continued

Variety	C. I. no.	California				Grand total		
		Acreage	Estimated yield per acre (bushels)	Total yield (bushels)	Percentage of crop	Acreage	Production (bushels)	Percentage of production
Blue Rose [2]	1962					441, 643	18, 493, 226	50. 13
Early Prolific [3]	5883					142, 264	6, 684, 401	18. 11
Caloro, Colusa [4]	1561-1	104, 940	76. 3	7, 998, 970	98. 63	114, 794	8, 470, 275	22. 95
Lady Wright	5451					21, 008	1, 096, 070	2. 97
Rexoro	1779					14, 783	707, 162	1. 92
Fortuna	1344					16, 193	695, 031	1. 88
Edith [5]	2127	2, 060	54. 0	111, 092	1. 37	13, 030	641, 650	1. 74
Nira	2702					2, 378	100, 786	. 27
Shoemed	3625					222	11, 743	. 03
Estimated total		107, 000		8, 110, 062	100. 00	766, 415	36, 900, 344	100. 00
Actual total [6]		105, 000		7, 665, 000		781, 000	38, 296, 000	

[1] Largely from Estimate of the Rice Crop for Year 1934, The Rice Millers' Association, Dec. 22, 1934.

[2] Blue Rose probably includes an undetermined area sown to the Improved and Supreme Blue Rose varieties.

[3] Includes a small acreage sown to Early Blue Rose in Arkansas.

[4] In California there is a small acreage sown to Onsen and Early Wataribune which is included with Caloro and Colusa, and in southern rice areas the short-grain rices are listed as Japan and probably include Acadia, Shinriki, Wataribune, and Caloro.

[5] Includes a small area sown to Storm Proof in Arkansas, and Peerless, Early Prolific, and Calady in California.

[6] General crop report as of July 1, 1935, U. S. Department of Agriculture, Bureau of Agricultural Economics.

TABLE 2.—*Breeding data on the rice varieties that have been and those that are now grown on a commercial scale in the United States*

Variety	C. I. no.	Year produced or obtained	By whom produced	In what way superior	Breeding method used	Source of parent material	Year distributed	1934 acreage
								Percent
Carolina White	1644	1685(?)	Chance introduction	Yielded well on delta lands of South Atlantic States; early long grain of good table quality but susceptible to diseases.	Introduction	Probably Madagascar	1685(?)	
Carolina Gold	1645	1685(?)	do	Same as Carolina White	do	do	1685(?)	
Honduras	1643	1890	Commercial introduction	Yielded well on delta lands and on new prairie land, early long grain of good table quality but susceptible to diseases.	do	Honduras	1890	
Kiushu		1899	S. A. Knapp, U. S. Department of Agriculture.	Yielded and milled well, short-grain rice of good quality.	do	Japan	1900	
Shinriki	1642	1902	do	Yields and mills well, stiff straw, late maturing, short grain of good quality.	do	do	1902	[2] 0.15
Wataribune	1561	1908	S. Sabaria, Webster, Tex	do	do	do	1908	
Omachi	1573	1910	Farmer, Crowley, La	do	do	do	1910	[1] .15
Blue Rose	1962	1907	S. L. Wright, Crowley, La	Yields and mills well, stiff coarse straw, late maturing, medium grain, fairly good quality, susceptible to diseases.	Selection	Japanese variety	1912	[2] 57.62
Improved Blue Rose	2128	1907(?)	do	do	do	do	1914	
Supreme Blue Rose	5793	1907(?)	do	do	do	do	1914–15	([3])
Early Prolific	5883	1907(?)	do	Yields and mills well, stiff coarse straw, early maturing, medium grain, poor quality, susceptible to diseases.	do	do	1915	[2] 18.56
Louisiana Pearl	1967	1907(?)	do	Yields and mills well, stiff coarse straw, late maturing, medium grain, fair quality, susceptible to diseases.	do	do	1916	
Edith	2127		do	Yields well on fertile land, fair milling quality, good table quality, early long grain, susceptible to diseases.	do	Honduras variety	1916	[1] 1.58
Colusa	1600	1909	Chas. E. Chambliss, U. S. Department of Agriculture and J. M. Jenkins, U. S. Department of Agriculture, Crowley, La.	Yields and mills well, fairly stiff straw, early short grain of good quality.	Pure line selection	Chinese variety from Italy 1909.	1917	[1] 2.12
Early Wataribune		1913	W. K. Brown, Butte City, Calif	Yields and mills well, fairly stiff straw, midseason short grain of good quality.	Introduction	Japan	1913	[1] .30

See footnotes at end of table.

TABLE 2.—Breeding data on the rice varieties that have been and those that are now grown on a commercial scale in the United States—Con.

Variety	C. I. no.	Year produced or obtained	By whom produced	In what way superior	Breeding method used	Source of parent material	Year distributed	1934 acreage
								Percent
Fortuna	1344	1911	Chas. E. Chambliss and J. M Jenkins.	Yields and mills fairly well, good table quality, long grain, fairly resistant to certain diseases.	Pure-line selection	Pa Chaim variety, Taiwan, 1905.	1918	2.11
Acadia	1988	1911	do	Yields and mills well, fairly stiff straw, late short grain of good quality.	do	Omachi variety, Japan, 1910.	1918	[1] .17
Delitus	1206	1911	do	Produces relatively low yields, fair milling quality, fairly stiff straw, early long grain of special flavor resembling pop corn.	do	Bertone variety, France, 1904.	1918	[4]
Tokalon	51	1911	do	Produces relatively low yields, fair milling quality, stiff coarse straw, medium long grain.	do	Carangiang variety, Philippine Islands, 1904.	1918	--------
Evangeline	1162	1911	do	Produces relatively low yields, fair milling quality, stiff straw, early long grain.	do	Unnamed variety, Guatemala, 1904.	1918	--------
Vintula	1241	1911	do	do	do	Unnamed variety, Ceylon.	1918	--------
Salvo	1297	1911	do	Produces relatively low yields, fair milling quality, stiff coarse straw, midseason long grain of special flavor.	do	Djember variety, Java, 1904.	1918	--------
Storm Proof	7705	1915	J. M. Satchfield, Technor, Ark	Produces relatively low yields, fair milling and table qualities, stiff straw, early long grain.	Selection	Honduras variety	--------	[1] .06
Mortgage Lifter	5550	1915	do	do	do	do		[1] .03
Greater Blue Rose	--------	--------	S. L. Wright	Yields and mills well, stiff coarse straw, late medium grain like Blue Rose.	do	Blue Rose variety	1918–19	--------
Early Pearl	--------	--------	do	Yields and mills well, stiff straw, late medium grain like Louisiana Pearl.	do	Louisiana Pearl	1918–19	--------
Onsen	--------	1918	Rice farmer, Biggs, Calif	Yields and mills well on fertile land, straw rather weak, early short grain of fair quality.	Introduction	Japan	1918	[1] .70
Butte	1564	1911	Chas. E. Chambliss and J. M. Jenkins.	Yields and mills well, straw rather weak, midseason short grain of good quality.	Pure-line selection	Tokyo variety, Japan	1917	--------
Improved Early Prolific.	--------	--------	S. L. Wright	Yields and mills well, fairly stiff coarse straw, early medium grain of rather poor table quality.	Selection	Early Prolific	1919	--------

Lady Wright	5451		do	Yields and mills fairly well, fairly stiff coarse straw, early long grain of rather poor table quality.	do	do	1920	[2] 2.75
Caloro	1561-1	1913	E. L. Adams, U. S. Department of Agriculture, Biggs, Calif., Chas. E. Chambliss, and Jenkin W. Jones, U. S. Department of Agriculture, Biggs, Calif.	Yields and mills well, fairly stiff straw, midseason short grain of fairly good quality.	Pure-line selection	Early Wataribune	1921	[1] 10.73
Texas Fortuna		1912	Texas Substation No. 4, Beaumont, Tex.	Yields and mills fairly well, stiff coarse straw, late long grain of good table quality, like Fortuna.	do	Pa Chaim variety, Taiwan, 1905.	1925	
Rexoro	1779	1926	Chas. E. Chambliss and J. M. Jenkins.	Yields and mills well, stiff straw, late long slender grain of very good table quality, resistant to some diseases.	do	Marong-paroc variety, Philippine Islands, 1911.	1928	[2] 1.93
Early Blue Rose		1929	G. H. Banks, Stuttgart, Ark	Yields and mills well, stiff coarse straw, early medium grain, like Early Prolific but more uniform.	Mass selection	Early Prolific	1930	[1] .39
Iola	4559	1926	Chas. E. Chambliss and J. M. Jenkins.	Yields well and mills fairly well, stiff coarse straw, late long grain, good table quality.	Pure-line selection	Finindoc variety, Philippine Islands, 1916.	1931	([4])
Nira	2702	1928	do	Yields well and mills rather well, stiff coarse straw, late long grain, good table quality.	do	Unnamed variety, Philippine Islands, 1916.	1932	[2] .31
Shoemed	3625	1928	do	Yields fairly well, does not mill so well, stiff straw, early medium grain, fairly good table quality.	do	Guinosgar variety, Philippine Islands, 1916.	1932	[2] .03
Peerless			Chas. S. Jurges, Dos Palos, Calif.	Yields fairly well on fertile land, mills poorly, early mostly long grain, uneven in maturity and grain type.	Selection	Natural hybrid	1933	[1] .28
Calady		1924	Jenkin W. Jones and L. L. Davis, U. S. Department of Agriculture, Biggs, Calif.	Yields and mills fairly well, stiff straw, midseason medium grain of good quality.	do	From cross, Lady Wright × Caloro.	1934	[1] .03

[1] Estimates based on information supplied by rice experiment stations.
[2] Estimates based on the Rice Millers Association report of Dec. 22, 1934.
[3] Included with Blue Rose.
[4] Grown on a small acreage in Louisiana.

TABLE 3.—*The characters in rice studied, ratios obtained in F_2, and the authority and year reported*

Character studied	Segregation in F_2	Ratio	Authority and year reported
Kernel color:			
Red × white	Red: white	3:1	J. E. van der Stok (1908); G. P. Hector (1913); F. R. Parnell, et al. (1917, 1922); J. W. Jones (1930).
Red × gray brown	Red: gray brown	3:1	F. R. Parnell et al. (1917).
Red × gold	Red: gold	3:1	F. R. Parnell et al. (1922).
Gold × yellowish	Gold: yellowish	3:1	Do.
Red × gold	Red: gold	3:1	Do.
Purple × white	Purple: white	3:1	Do.
Red × white	Red: pale red: white	1:2:1	G. P. Hector (1922).
Dark red × white	Red piebald: pale piebald: white.	1:2:1	Do.
Purple × brown	Purple: brown	9:7	F. R. Parnell et al. (1922).
Reddish brown × white	Reddish brown: yellowish brown: white.	9:3:4	I. Nagai (1921); S. Kato and J. Ishikawa (1921).
White × white	do	9:3.4	S. Kato and J. Ishikawa (1921).
Purple × white	Purple: red: white	12:3:1	F. R. Parnell et al. (1922).
Inner glume color:			
Red × white	Red: white	3:1	G. P. Hector (1913).
White × red	White: red	3:1	E. Thompstone (1915).
Colorless[1] × gold	Colorless: gold	3:1	F. R. Parnell et al. (1917, 1922).
Yellowish brown × black	Black: yellowish brown	3:1	G. P. Hector (1922).
Yellowish brown × red	Yellowish brown: red	3:1	Do.
Yellow × red	Yellow: red	3:1	Do.
Green × dark furrows	Green: dark furrows	3:1	F. R. Parnell et al. (1917).
Piebald × green	Piebald: green	3:1	Do.
Black × straw	Black: straw	3:1	Do.
Dark gold × ripening gold.	Dark gold: ripening gold	3:1	F. R. Parnell et al. (1922).
Dark furrows × ripening gold.	Dark furrows: ripening gold	3:1	Do.
Dark gold × piebald dark furrows.	Dark furrows: gold	3:1	Do.
Tawny × nontawny	Tawny: nontawny	3:1	L. F. Chao (1928).
White × white	Red: colorless (white)	9:7	S. Kato (1916)[2]
Black × straw	Black: straw	9:7	F. R. Parnell et al. (1917).
Gray × yellowish brown	Purple: reddish brown: dark gray: white.	9:3:3:1	S. Kato (1916).
Dark gray × orange streaked.	Dark gray: orange streaked: white: orange streaked.	9:3:3:1	Do.
Purple streaks × brown	Purple: purple streaks: brown: yellow.	9:3:3:1	I. Nagai (1921).
Yellow × red	Yellow: yellow and red: red	9:6:1	G. P. Hector (1922).
Colorless × yellowish brown.	Yellowish brown: colorless	13:3	J. W. Jones (1933).
Dark blackish violet × yellowish white.	Blackish violet: apex blackish violet: reddish brown: apex reddish brown: yellowish white.	27:9:9:3:16	Y. Yamaguchi (1921, 1926).
Inner glume apex and apiculi color:			
Red × green	Red: green	3:1	G. P. Hector (1916); J. W. Jones (1933).
Do	do	9:7	G. P. Hector (1916); J. W. Jones (1930).
Purple × colorless	Purple: red: colorless	9:3.4	J. W. Jones (1930).
Colored × colorless	Colored: colorless	15:1	G. P. Hector (1916).
Do	do	27:37	G. P. Hector (1916); L. F. Chao (1928).
Do	do	81:175	G. P. Hector (1916).
Purple × colorless	Purple: colorless	162:94	L. F. Chao (1928).
Outer glume color:			
Purple × nonpurple	Purple: nonpurple	3:1	I. Nagai (1921).
Tawny × nontawny	Tawny: nontawny	3:1	L. F. Chao (1928).
Colorless × red	Red: colorless	3:1	J. W. Jones (1933).
Purple × colorless	Purple: colorless	9:7	J. W. Jones (1930).
Colorless × red	Red: colorless	9:7	J. W. Jones (1933).
Awn color:			
Red × colorless (straw)	do	3:1	S. Kato (1916); G. P. Hector (1916); J. W. Jones (1930).
Black × reddish brown	Black: reddish brown	3:1	Y. Hoshino (1915).
Purple × red	Purple: red	3:1	S. Kato (1916); I. Nagai (1921).
Brown × colorless	Brown: colorless	3:1	I. Nagai (1921).
Tawny × nontawny	Tawny: nontawny	3:1	L. F. Chao (1928).
Purple × colorless	Purple: colorless	3:1	S. Kato (1916).
Red × White	Red: white	9:7	S. Kato (1916); J. W. Jones (1933).
White × white	do	9:7	S. Kato (1916).
Red × white	Purple: red: white	9:3:4	Do.
Purple × white	do	9:3:4	S. Kato (1916); J. W. Jones (1930).
Brown × colorless	Red: brown: colorless	9:3:4	I. Nagai (1921).

[1] Colorless and noncolor refer to the absence of color other than normal green or straw.
[2] The extensive work of S. Kato is reviewed by Ando in Bull. Dept. Agr. Japan, 2:1–102. 1916.

TABLE 3.—*The characters in rice studied, ratios obtained in F_2, and the authority and year reported*—Continued

Character studied	Segregation in F_2	Ratio	Authority and year reported
Stigma color:			
Colored × colorless	Colored: colorless	3:1	G. P. Hector (1916); L. F. Chao (1928).
Purple × green	Purple: green	9:7	L. F. Chao (1928); J. W. Jones (1930); S. K. Mitra et. al. (1928).
Colored × colorless	Colored: colorless	27:37	G. P. Hector (1916).
Do	do	81:175	Do.
Leaf blade color:			
Purple × green	Purple: green	3:1	S. Kato (1916); F. R. Parnell et al. (1922).
Green × pink	Green: pink	3:1	D. N. Mahta and B. B. Dave (1931).
Purple × green	Purple: green	9:7	S. Kato (1916); F. R. Parnell et. al. (1922).
Do	Green: purple	13:3	B. S. Kadam and V. K. Patankar (1934).
Do	Purple: green	27:37	Y. Takezaki (1921, 1923).
Leaf sheath color:			
Red × green	Red: green	3:1	G. P. Hector (1916); F. R. Parnell et al. (1917).
Reddish × green	Reddish: green	9:7	G. P. Hector (1916, 1922).
Color × noncolor	Color: noncolor	15:1	G. P. Hector (1922); L. F. Chao (1928).
Do	do	27:37	G. P. Hector (1922).
Purple × nonpurple	Purple: purple striped: green	27:9:28	J. W. Jones (1930).
Color of ligules:			
Colorless × purple	Purple: colorless	3:1	D. N. Mahta and B. B. Daue (1931).
Color × colorless	Color: colorless	9:7	G. P. Hector (1922); J. W. Jones (1930).
Do	do	27:37	G. P. Hector (1922); J. W. Jones (1930); L. F. Chao 1928).
Color of pulvinus and auricle:			
Purple × colorless	Purple: colorless	3:1	S. K. Mitra et. al. (1928).
Color × noncolor	Color: noncolor	9:7	G. P. Hector (1922); J. W. Jones (1930).
Purple × nonpurple	Purple: nonpurple	15:1	C. Fruwirth (1923).
Purple × colorless	Purple: colorless	27:37	J. W. Jones (1930).
Color of internodes:			
Color × noncolor	Color: noncolor	3:1	J. E. van der Stok (1909); G. P. Hector (1922); C. Fruwirth (1923); S. K. Mitra et. al. (1928).
Colorless × light purple	Light purple: colorless	3:1	S. K. Mitra et. al. (1928).
Colorless × light brown	Light brown: colorless	3:1	Do.
Purple lining × colorless	Purple lining: colorless	3:1	F. R. Parnell et. al. (1922).
Purple × colorless	Purple: colorless	9:7	G. P. Hector (1916); L. F. Chao (1928); S. K. Mitra et. al. (1928); J. W. Jones (1930).
Do	do	27:37	G. P. Hector (1916); J. W. Jones (1930).
Color of nodes:			
Purple × colorless	do	9:7	J. W. Jones (1930).
Do	do	27:37	T. E. Lee (1927); J. W. Jones (1930).
Presence of awns:			
Awned × awnless	Awned: awnless	3:1	K. Okada (1910); Y. Hoshino (1915); S. Kato (1916); J. W. Jones (1927).
Partly awned × fully awned.	Fully awned: partly awned	3:1	J. W. Jones (1933).
Fully awned × awnless	Fully awned: partly awned: awnless.	9:6:1	J. W. Jones (1927).
Awned × awnless	Awned: awnless	15:1	S. Kato (1916); I. Nagai (1926); L. F. Chao (1928); J. W. Jones (1933).
Grain or kernel length:			
Normal × large grain	Normal: large	3:1	H. Terao (1922).
Long × short	Short: intermediate: long	1:2:1	J. E. van der Stok (1909); C. Fruwirth (1923).
Length/breadth value, 3.00 × 3.85.	3.14: 3.44: 3.88	1:2:1	F. R. Parnell et al. (1922).
Grain weight, 2.145 g. × 1.755 g.	2.144: 2.075: 1.910 g.	1:2:1	Do.
Short × long	Multiple factors		J. W. Jones et al. (1935).
Short × medium	do		Do.
Medium × long	do		Do.
Stature:			
Normal × dwarf	Normal: dwarf	3:1	F. R. Parnell et al. (1922); M. Akemine (1925); J. W. Jones (1933).
Do	Dwarf: normal	3:1	S. Sugimoto (1923).
Dwarf × dwarf	Normal: dwarf (first type): dwarf (second type): dwarf (third type).	9:3:3:1	M. Akemine (1925).

TABLE 3.—*The characters in rice studied, ratios obtained in F_2, and the authority and year reported*—Continued

Character studied	Segregation in F_2	Ratio	Authority and year reported
Stature—Continued.			
High × low	Tall: short	3:1	K. Ramiah (1933).
Do	Short: tall	3:1	Do.
Do	do	13:3	Do.
Do	Multiple factors		S. Kato (1916); J. W. Jones (1928); K. Ramiah (1933).
Maturity:			
Early × late	Late: early	3:1	M. Nomura and R. Yamazaki (1925); R. K. Bhide (1926); J. W. Jones (1933); J. W. Jones et al. (1935).
Do	*Early: late*	3:1	*K. Ramiah (1933).*
Early × early	*Late: early*	9:7	*J. W. Jones et al. (1935).*
Early × late	*Multiple factors*		Y. Hoshino (1915); B. Miyazawa (1916); J. W. Jones (1928); J. W. Jones et al. (1935).
Chlorophyll deficiencies:			
Normal × yellow seedlings	Normal: yellow	3:1	S. Morinaga (1927).
Normal × albino seedlings	Normal: albino	3:1	Do.
Green × white striped	Green: white	3:1	S. K. Mitra et al. (1928).
Green × yellow	Green: yellow	3:1	S. Morinaga (1927); B. S. Kadam and V. K. Patankar (1934).
Normal × albino	Normal: albino	9:7	S. Morinaga (1927).
Variegated × green	Green: yellow	15:1	Do.
Green × yellow	Green: white	15:1	B. S. Kadam and V. K. Patankar (1934).
Green × green	Green: albino	63:1	L. E. W. Codd (1935).
Sterility:			
Fertile × semisterile	Fertile: semisterile	3:1	H. Terao (1921); J. Ishikawa (1927).
Fertile × partially sterile	Fertile: partially sterile	3:1	I. Nagai (1926); M. Kondo (1927).
Fertile × staminodal sterile.	Fertile: staminodal sterile	3:1	I. Nagai (1926).
Fertile × awned sterile	Fertile: awned sterile	3:1	Do.
Fertile × paleaceous sterile.	Fertile: paleaceous sterile	3:1	Do.
Fertile × male sterile	Fetile: male sterile	3:1	J. Ishikawa (1927).
Fertile × completely sterile.	Fertile: completely sterile.	3:1	S. Sugimoto (1923).
Disease resistance:			
Resistance × susceptibility to *Leptosphaeria* (Catt.)		3:1	S. Kato (1916).
Resistance × susceptibility to *Melanomma oryzae*.		3:1	Do.
Resistance × susceptibility to *Piricularia oryzae*		3:1	R. Sasaki (1922).
Do		9:7	S. Nakatomi (1926).
Miscellaneous characters:			
Normal × aberrant panicle	Normal: aberrant	3:1	M. Kondo and S. Fujimoto (1927).
Normal × compact panicle	Normal: compact	3:1	R. K. Bhide (1926); I. Nagai (1926).
Long × short panicle	Multiple factors		S. Kato (1916); R. K. Bhide (1926).
Compact × loose grain arrangement.	do		S. Kato (1916).
Easy × tough chaff separation.	Easy: tough	3:1	J. Onodera (1929).
Tough × easy chaff separation.	Tough: easy	3:1	Do.
Starchy × glutinous endosperm.	Starchy: glutinous	3:1	S. Ikeno (1914); Y. Hoshino (1915); S. Kato (1916); Y. Yamaguchi (1918).
Nonshattering × shattering.	Nonshattering: shattering	3:1	S. Kato (1916); J. W. Jones (1933).
Normal ligules × liguleless	Normal ligules: liguleless	3:1	Do.
Brittle × normal culms, etc.	Normal: brittle	3:1	J. W. Jones (1933).
Short × long outer glumes.	Short: long	3:1	K. Okada (1910); F. R. Parnell et al. (1917); J. W. Jones (1933).
Do	do	15:1	L. F. Chao (1928).
Sinuous × normal neck	Normal : sinuous	15:1	J. W. Jones (1928).
Breadth of leaf	Multiple factors		S. Kato (1916).
Diameter of stem	do		Do.
Yield	do		R. K. Bhide (1926); J. W. Jones (1928).

Institutions and Stations at Which Rice Improvement Work is Being Conducted, or from Which Information Can Be Obtained

India:

Imperial Institute of Agricultural Research (Bihar Province), Pusa.[16]
Imperial Institute of Agriculture (Madras), Coimbatore.[16]
Rice Breeding Station (Madras Province), Coimbatore.
Rice Breeding Station (Bombay Presidency), Karjat.[16]
Rice Breeding Station (Bombay Presidency), Larkana.[16]
Poona Agricultural College (Bombay Presidency), Poona.
Dacca Central Farm (Bengal Province), Dacca.[16]
Rice Experiment Station (United Provinces), Cawnpore.
Rice Experiment Station (Punjab Province), Kala Sha Kaku.
Rice Experiment Station (Burma), Hmawbi.[16]
Rice Experiment Station (Burma), Mandalay.
Rice Experiment Station (Burma), Myaungmya.[16]
Rice Experiment Station (Burma), Mudon.
Sabour Agricultural Station (Bihar and Orissa), Sabour.[16]
Nagpur Agricultural College (Central Provinces), Nagpur.[16]
Rice Experiment Station (Assam Province), Titabar.[16]
Rice Experiment Station (Mysore State), Nagenhalli.
Rice Experiment Station (Travancore State), Nagercoil.
Sakarand Agricultural Research Station (Sind Province), Sakarand.[16]

China:

Rice Experiment Station (Kiansu), Soochow.
Rice Experiment Station, Bureau Agriculture and Forestry, Canton.
Central Agricultural Experiment Station, Nanking.
Agricultural Experiment Station, Central University, Nanking.
Agricultural Experiment Station, Nanking University, Nanking.
Agricultural Experiment Station, Chekiang University, Hangchow.
Agricultural Experiment Station, Chung San University, Canton.
Agricultural Experiment Station, Lingnan University, Canton.

Japan:

Imperial Agricultural Experiment Station, Tokyo Imperial University, Tokyo (Nishigahara).
Imperial Agricultural Experiment Station, Kyoto Imperial University, Kyoto.
Imperial Agricultural Experiment Station, Sendai Imperial University, Sendai.
Imperial Agricultural Experiment Station, Kyushu Imperial University, Fukuoka.
Imperial Agricultural Experiment Station, Sapporo Imperial University, Sapporo.
Central Agricultural Experiment Station, Suigen (Chosen).
Department of Agriculture, Government Research Institute, Taikoku (Taiwan).
Ohara Institute, Kurashiki.

Java:

Central Agricultural Experiment Station, Division of Annual Crops, Buitenzorg.

Philippine Islands:

Bureau Plant Industry, Department of Agriculture (Rizal), Manila.
Alabang Rice Experiment Station (Rizal), Alabang.
Pangasinan Rice Experiment Station (Pangasinan), Pangasinan.
Maligaya Rice Experiment Station (Nueva Eciji), Munoz.
Agricultural Experiment Station, College of Agriculture (Laguna), Los Banos.

British Malaya:

Department of Agriculture, Kuala Lumpur.
Titi Serong Rice Experiment Station, Titi Serong.
Pulau Gadong Rice Experiment Station, Pulau Gadong.

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[16] Principal rice-breeding stations in India.

Indochina:

Institute of Agricultural Research, Saigon.

Indochina Rice Office:

Paddy Station (Tonkin), Bac Giang.
Paddy Station (Cochinchine), Cantho.
Paddy Station (Cochinchine), Phuloc.
Paddy Station (Cochinchine), Gocong.
Paddy Station (Tonkin), Phuclong.

Ceylon:

Agricultural Experiment Station, Department of Agriculture, Peradeniya.

Madagascar:

Experiment Station of Ivoloina, Tamatave.
Experiment Station of Nasisana, Tananarive.
Agricultural Experiment Station of Alaotra, Ambohitsilaozama.
Paddy Station of Marovoary, Marovoary.

Africa:

Kenema Substation (Sierra Leone), Kenema.
Experimental Farm of Mwanza, Mwanza.

Siam:

Ministry of Commerce and Agriculture, Bangkok.

Spain:

Sueca Rice Experiment Station, Sueca.

Italy:

Rice Experiment Station, Vercelli.

Egypt:

Ministry of Agriculture, Botanical and Plant Breeding Section, El. Giza.

Union of Soviet Socialist Republics:

Lenkoran (Azerbaidjan) Rice Station, Lenkoran.
Central Experimental Rice Station, Krasnodar.

United States:

United States Department of Agriculture, Bureau of Plant Industry, Division of Cereal Crops and Diseases, Washington, D. C.
Rice Branch Experiment Station, Stuttgart, Ark.
Rice Experiment Station, Crowley, La.
Texas Agricultural Substation No. 4, Beaumont, Tex.
Biggs Rice Field Station, Biggs, Calif.

British Guiana:

Central Rice Experiment Station, Georgetown.

Dutch Guiana:

Agricultural Experiment Station, Paramaribo.

Peru:

Lambayeque Experimental Station, Lambayeque.
Agronomic Station, Piura.
Agronomic Station, Loreto.

Chile:

Station of Genetics of the Ministry of Agriculture, Los Andes.

Argentine:

University of La Plata, Department of Agronomy, Decano.

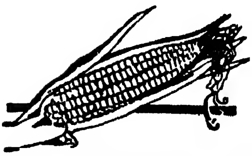
Brazil:

Institute of Agronomy of Campinas, Campinas, Sao Paulo.

Australia:

Department of Agriculture New South Wales. Plant Breeding Branch, Sydney.

Corn Improvement



By Merle T. Jenkins, Principal Agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry

CORN, THE MOST TYPICAL AMERICAN PLANT, YIELDS RICH RESULTS IN BREEDING AND GENETICS

FOR Americans it is peculiarly fitting that great advances, both in theoretical genetics and in practical plant breeding, should have been made with corn, the foremost American cereal.

No other organism except the pomace fly has yielded as rich results in theoretical genetics. Research scientists have now reached the point where they know the inheritance of some 350 genes in corn, and can definitely map or locate about a hundred of them in the chromosomes of the cell. The advance in theoretical knowledge has reacted on practical breeding by opening up new trails and making the breeder more sure of his ground.

The latest development in corn breeding, hybrid corn, comes nearer to the actual creation of new kinds of corn plants by what might be considered the equivalent of laboratory methods than anything previously done. These new creations are built up by the corn breeder out of inbred lines, the building materials of his trade. So far each breeder has had to develop most of his own building materials by inbreeding for five or six generations in adapted strains and selecting lines suited to his particular conditions.

During the inbreeding process various complements of the good and bad traits of the parents become fixed in the different inbred progeny. Many of the progeny may receive an overdose of the bad traits and as a result are unable to survive. Their evil inheritance wipes them out. Others receive a preponderance of good traits and are preserved.

In all of the inbred lines so far developed, yield has dropped rapidly with the continued inbreeding. Starting, say, with 60 bushels per acre for the parent variety, it may drop to 20 or 30 bushels or less by the fifth or sixth generation of inbreeding. The outstanding merit of inbred lines is that the plants in a given line are essentially alike in their inheritance.

When these inbred lines are crossed and the hybrid seed is planted, from it may develop vigorous plants, remarkably uniform over the entire field and extraordinarily productive. Lines that produce 20 to 30 bushels per acre may, when crossed, yield 70 bushels per acre or

better—considerably more than the 60-bushel variety that served as the starting point for inbreeding several generations back.

These startling results, however, hold true only for the first hybrid generation. Seed from this hybrid corn produces plants that are far from uniform, with many of them decidedly inferior. Hybrid corn, in other words, must be the product of a fresh cross—first-generation seed, produced each season from inbred parents maintained solely for that purpose.

Striking as this method is, it must be regarded as only a beginning. The corn breeder can look ahead and predict with some certainty that still better results will be possible, with much greater sureness in technique.

Hybrid corn will be considered in greater detail later in this article. Before that, however, it would be well to trace the early history of the corn plant briefly, and tell something about the manner of reproduction in corn, which underlies the breeding technique.

Importance of Corn as the Backbone of American Agriculture

OF ALL the things that are characteristic of America, corn is perhaps the most characteristic. The discovery of America was the discovery of corn. There was a corn civilization in this country before the coming of Columbus, especially among the Aztecs, the Mayas, and the Incas, and in a very real sense there still is a corn civilization. The important part played by corn in the early civilizations is indicated by numerous relics, one of which is reproduced in figure 1.

The word "corn," the common term used in this country to designate Indian corn or maize, comes from the Saxon corn (Teutonic korn), which is a general term for any cereal. It is often used in any particular country to designate the cereal most extensively consumed there for human food. In England "corn" and "corn trade," as the terms generally are used, refer to wheat.

Maize is an Arawak word, many forms of which are met with in South America and the West Indies, as mahiz, marisi, marichi, mariky, mazy, and maysi. This name followed the introduction of the grain into Europe and still is commonly used there, being variously spelled maize, maiz, mais, mays, mayz, or mayze. As the word "maize" dates back to the introduction of the crop into the Old World, it has the highest claim to recognition for universal use, and many recent American writers on cereals have endeavored to introduce the term into this country as a substitute for the term "corn."

The importance of corn to the early English settlers at Jamestown and Plymouth can hardly be overestimated. Had it not been for the corn these early settlers received from the Indians, their colonies would undoubtedly have ended in melancholy tragedies and the settlement and development of the New World would have been delayed for perhaps a century. Gov. William Bradford's History of Plymouth Plantation relates that on November 15, 1620, a party of 16 Pilgrims

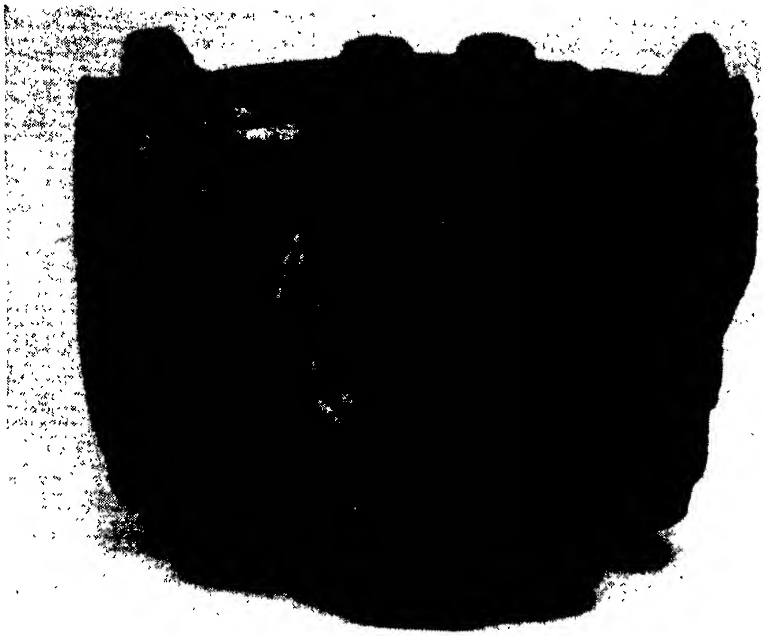


FIGURE 1.—An Aztec urn bearing facsimiles of excellent ears of corn. Many of the kernels are distinctly dented like those of some of our present varieties. (After Kempton, courtesy W. E. Safford.)

under conduct of Capt. Miles Standish spied five or six Indians whom they followed all that day. The next morning they found "new-stuble wher corne had been set ye same year . . . and heaps of sand newly padled with their hands, which they, digging up, found in them diverce faire Indean baskets filled with corne, and some in eares, faire and good, of diverce collours, which seemed to them a very goodly sight, (haveing never seen any shuch before)."

Today corn is the backbone of American agriculture. The United States, the principal corn-producing country, grows roughly three-fourths of the world supply. It is grown in every State in the Union, about 100 million acres being planted to the crop each year. It exceeds in production and value the combined crops of wheat, oats, barley, rye, rice, and buckwheat. The principal use of corn is as a feed for livestock, about 80 percent being fed to stock on the farms where it is grown.

This article discusses some of the advances that have been made in our knowledge of the theory and practice of corn breeding and attempts to list the present supplies of superior breeding material. Such a mass of data has been accumulated during the past 25 years on theoretical corn breeding, genetics, and cytology that these subjects cannot be reviewed in any great detail within the limitations of this article. Several comprehensive reviews that have appeared recently in the technical literature are available to those interested in detailed information, and references to these reviews are given in the proper place.

The practical development of varieties that are inherently more productive than those now used is of great economic importance to

American agriculture. Developments in the theoretical knowledge of breeding that in turn make the production of improved varieties possible is of equal economic importance, although that fact is not so widely appreciated.

The Origin of Corn Remains a Mystery and a Subject of Speculation

IF WE may judge from purely botanical evidence, corn is probably the oldest of cultivated cereals, if not of all cultivated plants. In its present form it is totally unsuited to exist in the wild. In order to reach its present condition of apparent helplessness from the standpoint of self-perpetuation, corn must have been grown by human beings ever since it has been enough like the present plant to be classified as corn. The time required for corn to reach its present development cannot be estimated with any accuracy, but it must have taken many thousands of years.

The origin of the corn plant has been the subject of almost as much speculation and controversy as the origin of man himself, largely because no wild forms of corn have been found. Several hypotheses have been advanced, but none of them is entirely satisfactory.

Early accounts of corn contain many references to pod corn as a wild or primitive type. For many years pod corn went under the name of "Wild Corn" or "Rocky Mountain Wild Corn." The distinguishing feature of podded corn is that each kernel is separately enclosed in a husklike structure, in addition to the husks that cover the entire ear. Pod corn is as unable to exist in the wild as is the usual type of corn. Genetic investigations have shown that the podded condition differs from the usual type by only one dominant inherited factor, present in the heterozygous (hybrid) condition.

Most of the recent hypotheses regarding the origin of corn make reference to teosinte, its closest wild relative. This plant is a tall grass, native to certain sections of southern Mexico and Central America (see later section entitled "Some of the Botanical Relatives of the Corn Plant"), where it often occurs at the present time as a weed in the margins of cornfields. It resembles corn in many respects and crosses readily with corn. A teosinte plant is shown in figure 2. It is sometimes grown by Indians in Mexico as a fodder plant, but its seeds have a very horny covering and it is of no value as a grain crop.

One hypothesis to account for the origin of corn assumes that it arose from teosinte or from some of the ancestors of teosinte. There is no reliable evidence that teosinte ever has been of use to man except as a forage plant. The early inhabitants of Mexico had no domesticated herbivorous animals and therefore no reason for cultivating a plant for forage purposes. Paul Weatherwax, a proponent of this hypothesis, points out, however, that a single hereditary change which would cause the teosinte grain to extend well beyond its normal bony covering would be of sufficient economic importance to these early inhabitants to merit propagation by them.

According to another hypothesis, corn is descended from some unknown wild plant that has since disappeared or, if still in existence,

FIGURE 2.—Annual teosinte (*Euchlaena mexicana*), the closest wild relative of corn: *A*, Teosinte plant; *B*, teosinte ear; *C*, teosinte ear with husks removed (no cob).

has never been discovered. This suggestion disregards the close relationship between corn and teosinte.

Still another holds that corn arose through the hybridization of teosinte with some plant bearing edible seeds. G. N. Collins and J. H. Kempton believe that the characteristics of sorghum might combine with those of teosinte to produce a parent from which corn may have developed. An objection raised to this hypothesis is that up to the present time it has not been possible to cross sorghum with either corn or teosinte.

Two locations commonly advanced as possibilities for the origin and domestication of corn are (1) the highlands of Peru, Bolivia, and Ecuador and (2) an area in southern Mexico and Central America. The great diversity of native forms of corn occurring in the highlands of Peru, Bolivia, and Ecuador suggest this region because this condition usually obtains in the native habitat or place of origin of a species. The chief objection to these high areas as the place where corn originated lies in the fact that teosinte does not occur in this section. In southern Mexico and Central America, the native home of teosinte, there is also a very wide diversity of corn types. This, taken together with the close relationship between corn and teosinte, makes it seem most probable that corn originated in this region.

CORN TODAY IS MUCH LIKE THAT CENTURIES OLD

The first definite date in the history of corn is November 5, 1492, when the plant was brought to the attention of Columbus. Columbus refers to it as growing in Cuba, Santo Domingo, Trinidad, and the mainland of South America. In writing to Ferdinand and Isabella of Spain, he mentions cornfields 18 miles in length.

When the first white settlers reached North America they found the Indians growing native varieties of flint, flour, gourdseed-dent, pop, and sweet types. There is evidence that the Indians also had dent types, not unlike our present dents but evidently much more restricted in their distribution. In fact, the facsimile ears on the Aztec urn shown in figure 1 have many kernels that are dented much like some of our present dent varieties.

Ears from prehistoric American graves indicate that there has been little change in the crop over many centuries. Graves in Peru and Bolivia have yielded wonderfully preserved ears which show no characteristics not found in present types and some of which might even be classed as belonging to present-day Peruvian or Bolivian varieties. Utah graves of the Basket Maker Indians, the earliest inhabitants of the Southwest of whom we have records, have yielded ears very similar to those grown by the present Indians in the same territory.

The corn plant of today is little different from the plant Columbus found when he discovered this country. The present well-bred varieties of flint, flour, pop, and sweet differ from the early Indian varieties mainly in their greater uniformity. The principal accomplishment of the white man in the four and a half centuries since America was discovered has been the development of the present dent varieties, possibly some of them from mixtures of flint with the extreme gourdseed types of dent, and their gradual extension throughout the corn-growing area as a result of the selection of adapted strains.

Following the return of Columbus, corn spread from Spain to France, Italy, and Turkey. In some sections of Europe it was known for many years as "Turkish wheat," having probably reached them by way of Turkey. After its introduction into the Old World, corn spread rapidly into every country and province where the climate was suited to it. Apparently it reached China and Africa during the sixteenth century.

MOST COMMERCIAL VARIETIES HAVE COME FROM OPEN-POLLINATED PLANTS

The improvement of corn through breeding and better cultural practices has occupied the attention of growers since the days of its discovery. The first reported efforts for this purpose that have come to the writer's attention were made in 1623. In the spring of that year, after a winter of privation and suffering through food scarcity, the Pilgrims "begane to thinke how they might raise as much corne as they could, and obtaine a beter crope than they had done . . ."

For convenience, the developments in corn breeding, corn genetics, and corn cytology will be discussed under separate headings. It must be emphasized, however, that these three related sciences have developed simultaneously, the advances in each field contributing to and drawing from those in the other fields.

With few exceptions the varieties in commercial production at the present time have been developed by various methods of selection, or hybridization followed by selection, among open-pollinated plants. Hybrid strains resulting from the crossing of selected inbred lines are just beginning to come into production in appreciable quantities. The well-selected, adapted, open-pollinated varieties, therefore, still represent our principal reservoir of superior germ plasm. They are our heritage from past breeders and constitute a major source for the superior inbred lines of the future.

Varietal names of corn mean less than those of almost any other field crop. Because of its cross pollination, corn is maintained in an extremely heterozygous condition. This requires that consistent selection be practiced over long periods to develop and maintain any reasonable uniformity of type within varieties. The variations in the ideals and methods of selection of different breeders have resulted in the development of widely different varietal types and likewise in the isolation of innumerable strains within all of the important varieties. In fact, it has often been shown in yield trials that there may be larger differences among strains within varieties than between the varieties. In spite of these difficulties, varietal names in corn have some significance, and State experiment stations make varietal recommendations, assuming the use of adapted strains. The varieties recommended by the different State experiment stations for grain production in their respective States are listed in the appendix (p. 496).

The history of corn breeding may be discussed for convenience under the general headings of mass selection, ear-to-row selection, and modern corn breeding, the last involving selection within and among inbred lines. The first two methods largely involve selection among open-pollinated plants as contrasted with selection under controlled pollination.

The Story of Corn Breeding, from Mass Selection to Modern Hybridizing

IN ORDER to understand the relative merits of different methods of breeding corn, it is necessary to know how the corn plant reproduces. Corn ordinarily is monoecious, that is, the stamens and pistils are borne in separate inflorescences on the same plant. The staminate or male flowers are in the tassel, a panicle at the top of the stalk. The pistillate or female flowers are borne in spikes, the ears, placed in the axils of leaves usually near or below the central portion of the plant. Staminate and pistillate inflorescences of corn are shown in figure 3.

In 1694 Camerarius, an early botanist, reported the first experiments demonstrating the existence of sex in plants. His experiments

FIGURE 3.—The inflorescences of corn: *A*, Staminate; *B*, pistillate.

were performed with the mulberry, castor-bean, and Indian corn. He removed the silks from corn and proved that pollen of corn was necessary to fertilize the ovules in order that the kernels might develop.

In 1716 Cotton Mather, an American whose name has been popularly associated with witch hunting, reported what are probably the first observations on natural crossing of corn varieties and the immediate effect of pollen on cross-fertilized seeds. His observations are described in a letter to James Petiver, dated September 24, 1716, which is quoted in part as follows:

First: my Friend planted a Row of *Indian Corn* that was Coloured Red and Blue; the rest of the Field being planted with corn of the yellow, which is the

most usual colour. To the Windward side, this Red and Blue Row, so infected Three or Four whole Rows, as to communicate the same Colour unto them; and part of ye Fifth, and some of ye Sixth. But to the Leeward Side, no less than Seven or Eight Rows, had ye same Colour communicated unto them; and some small Impressions were made on those that were yet further off.

The pollen grains of corn develop in the anthers of the staminate flowers in a manner typical of most flowering plants. The pollen mother cells divide twice to give rise to four immature pollen grains. One of these divisions is a reduction division, in which the number of chromosomes is reduced by half, and the other an equational division, where each chromosome divides and a representative of each one is present in the two daughter cells. These different kinds of cell division are explained in the general introduction and glossary of this Yearbook. The nucleus in each young pollen grain divides to form a tube nucleus and a generative nucleus. The generative nucleus again divides to form two sperm nuclei of identical genetic composition, which are present as crescent-shaped bodies in the mature pollen grain.

The formation of the embryo sac within the ovary at the base of each silk (fig. 4) also occurs in a manner similar to that of most other flowering plants. The egg mother cell divides twice, one division being a reductional division and the other an equational division, to produce four potential megaspores. Three of these degenerate and the one remaining gives rise to the embryo sac. The mature embryo sac contains eight nuclei of identical genetic composition, one of which functions as the egg. Two others, the two polar nuclei, are concerned in endosperm development.

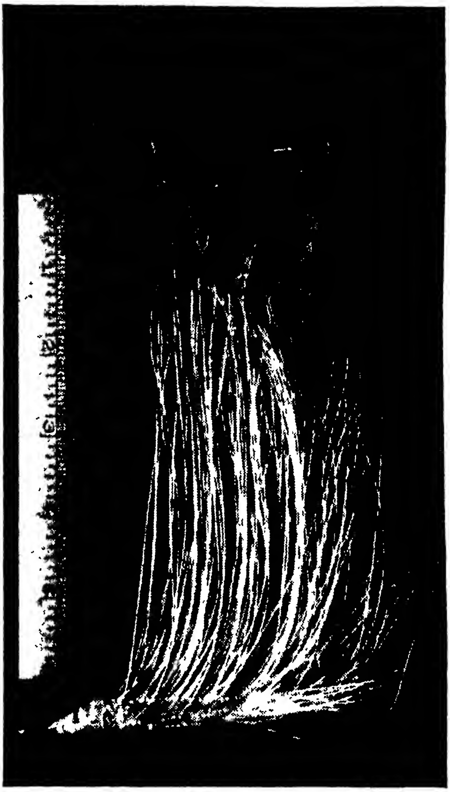


FIGURE 4.—Young ear shoot with the husks removed to show the development of the silk from the tip of each ovary. Each silk must receive pollen in order for that kernel to develop.

When the yellow pollen, the "gold dust" of the Corn Belt, matures, it is liberated from the anthers and carried through the air at random by the wind. Some of the grains fall upon receptive silks, where they germinate and send pollen tubes down through the silks (fig. 5). The tube nucleus functions in the formation of the pollen tube. The two sperm nuclei travel down the tube and are discharged into the embryo sac. One of them unites with the egg cell and from this fertilized egg the embryo or "germ" of the kernel develops. The other unites with the two polar nuclei, and from this union the endosperm portion of the kernel develops. Thus the male contributions to the embryo and endosperm are identical. The female

contributions are alike genetically but are twice as great to the endosperm as to the embryo.

From this brief description of reproduction in corn, it is clear that each kernel on an ear may be pollinated with pollen from a different male parent plant. For this reason selecting an open-pollinated ear from a good plant is selecting only the female half of the parentage. The male side of the parentage can be controlled only by controlling the source of the pollen.

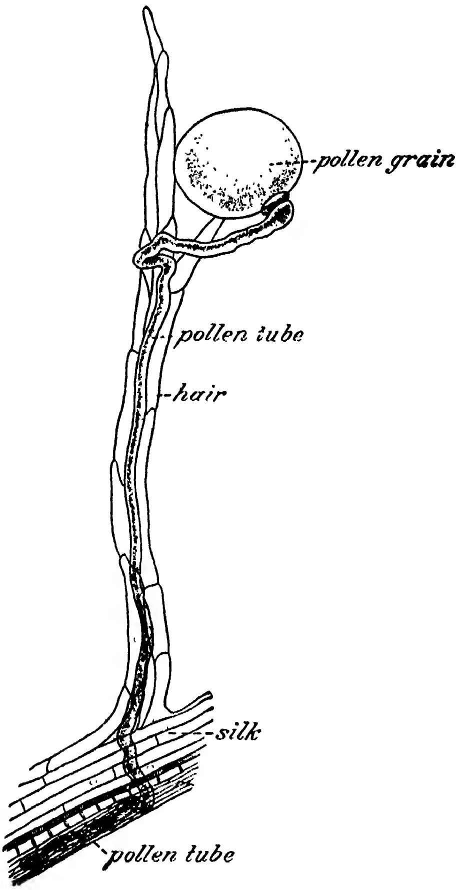


FIGURE 5.—Germinating pollen grain (after Miller).

Under favorable conditions corn pollen may be carried great distances and effect fertilization. Unfavorable conditions at pollinating time, however, may interfere seriously with seed setting. A hot, dry wind may wither the tassels so that pollen is not liberated or it may wither the silks so that they are not receptive, or it may so dry out the pollen floating through the air that it will not germinate when it reaches the silks.

EARLY BREEDERS WERE ARTISTS IN THE USE OF MASS SELECTION

Mass selection consists in choosing certain desired individuals from the main crop and planting en masse the seed harvested from them. A certain amount of mass selection has been practiced by corn growers since the earliest times. Corn ears are large, and, in the past at least, each ear had to be handled individually both at harvest and in the preparation of seed, so that the planting of a mixture of seed without selection can hardly be imagined. There is ample evidence that this selection has been of the utmost importance in improving corn and adapting it to the varying conditions under which it is grown.

The early corn breeders were artists in molding the form of the corn plant and the corn ear to fit their will. Each breeder had very definite opinions as to the ideal type of plant and of ear and selected rigorously with these ideals in mind. Mass selection was the only tool of the breeders, but they were experts in its use. They had no knowledge of the fundamental laws of inheritance and thus were limited in the range of their accomplishments.

The history of Reid Yellow dent may be cited as a typical example of the place of mass selection in the development of present-day

Pedigree History Sheet

Origin and History of Blount's White Prolific *Variety of Corn as given by* Prof. A. E. Blount, *P. O.* Cleveland E. Tenn. *State* from 1866 to 1877

B. P. I. Corn Investigations. Form 6.

Name and address of originator Prof. Ainsworth E. Blount now of Wellesley Mass.

If originator is deceased, name in order those who have continued the improvement of the variety, [illegible] only bred up this variety from start to finish without any assistant whatever.

If this variety is the result of crossing other corns, give date crossing occurred and a brief description of the corns crossed, Only this and no other was improved by crossing upon itself every year the best on the best to obtain more prolific, uniform full and firm seed for next season's planting.

Do the characters of the corns crossed still show in this variety? [illegible] left off breeding it up in

Give the date on which the improvement of this variety began and methods employed since that date,

1896. 7. 8. Every characteristic and habit perfect and not a single ear showed signs of foreign mixture on 4 acres

Is this variety now uniform as regards stalks? Not now. It has regards ears? not been kept bred up to pedigreed grade by experts, hence greatly deteriorated

This variety matures in about 90 days from date of planting. On good corn soil the stalks attain an average height of 6 to 7½ feet, and average about 4 to 6 10 oz. ears per stalk. Ears average about top ear 4 feet from the ground and others [illegible] nubbins clear to the ground.

In 100 stalks tillers or suckers will usually be found to the number of no suckers, on every node or joint

Ears are White dent in color, with only 13% cobs Good seed ears average 12 to 14 inches long and 2¼ diameter inches in ~~circumference~~ one-third of the distance from the butt, and about 2 in. diameter inches one-third of the distance from the tip.

Number of average ears required to weigh 100 pounds is 150 to 160. 100 pounds of ears will yield 87% pounds of shelled corn after 30 days [illegible]

Average number of rows of kernels per ear is 8 always, with 46 to 57 kernels per

Kernels are like steel nail long, round wide, [illegible] thick, and weigh 57½ lb. per struck bushel. after 30 days hanging

The best features of this variety are Prolific character; pedigreed; pure without a grain of mixture when I left off breeding it in 1896.

The most objectionable features of this variety ~~are~~ is Only one, stalks below 4 to 6 top ears too long. Ears and nubbins on every joint clear to ground. Ears perfectly were filled to tip of all normal stalks. Not a single grain or row missing

Use space below for explanations or additional information.

Seed improvement: the prolific habit from an ear and 2 nubbins the first year 15 to 16 good 10 oz ears on 2/3 stalks of 4 acres the 10th year the period of maturity was shortened from 121 days the first year to 90 days the 10th year

The whole crops for 10 years were protected and kept pure by covering every seed ear intended for seed the next year with a thin paper bag and when the silks were fully out under the bag it was removed and pollen from the tassels of the best stalks was collected and poured into the cluster of silks and the bag returned to keep out all foreign

FIGURE 6.—History of Blount White Prolific as reported to the Bureau of Plant Industry by A. E. Blount in 1910.

varieties. Robert Reid moved from southern Ohio to central Illinois in 1846. He took with him a late semigourdseed variety known as Gordon Hopkins corn. The seed was not planted until quite late in the spring, but made a fairly good crop of immature corn. Although the best of this was selected for the next year's planting, it resulted in a poor stand in the spring of 1847. The missing hills were replanted with a small local variety called Little Yellow Corn, probably a flinty type. From the resulting crop, which presumably had a considerable amount of interpollination, the variety Reid Yellow Dent was developed after many years of careful selection by James L. Reid, a son of Robert Reid. Similarly many other varieties have been developed from previously existing varieties, from mixtures, or from varietal hybrids by the painstaking selection of interested breeders.

In most cases the mass selection has been among open-pollinated plants. The first case which has come to the writer's attention where consideration was given to the source of the pollen was reported by H. S. Bidwell in the American Agriculturist for December 1867, which states in part:

> A remarkable fact has lately been brought to our attention by Mr. H. S. Bidwell, (Bidwell Bro's.,) of St. Paul, who was recently traveling in Tennessee, where he saw a field of common corn, which usually yields an average of not more than one good ear to the stalk, bearing almost uniformly two, and often three ears. The result, he informs us, had been brought about in this way. It occurred to the farmer that, as the kernel usually derived its origin, as we have described, from two different plants, saving the seed corn from stalks bearing two ears was not enough; he must see to it that the kernel germs were fertilized by similar stalks. So he planted every year a special patch for seed, and carefully cut off all the spindles on stalks where two or more ears were not set. The result was an improvement year by year in the quantity of corn, as well as in the manner in which it grew. The principle has a wide application in the improvement of the different kinds of farm and garden produce. In the breeding of animals, the qualities expected from the male, and those which usually are inherited from the dam, are to a degree understood, and the application of similar principles in breeding vegetables is certainly legitimate. The fact above stated has so good a foundation in sound reasoning, that we give it to our readers, anticipating its publication in the "American Agricultural Annual" which is now in press.

The report mentioned as about to appear in the Agricultural Annual appeared in the Annual for 1868. This report states that the tassels (spindles) were removed before the silks appeared.

The writer has been unable to identify the Tennessee farmer referred to. It may not be entirely a coincidence, however, that what is believed to be the first case involving mass selection and controlled pollination also is reported from Tennessee. About this time A. E. Blount began controlled pollination in a variety of white corn. The ear shoots of 100 to 300 desirable plants were covered with muslin each season. These selected plants were hand-pollinated with pollen of other desirable plants selected as male parents. The resulting variety, called Blount White Prolific, came to the attention of the Rural New Yorker about 1879 and was widely distributed by them. Accounts of Blount's breeding methods and the performance of the variety appeared frequently during the following 3 or 4 years. A history of the variety supplied to the Bureau of Plant Industry in 1910 at the request of C. P. Hartley is shown in figure 6. Blount Prolific still is grown in some sections of the South.

In later years Blount was located first at the Colorado and then at the New Mexico Agricultural Experiment Station, in each case continuing his work of improving corn by the same method of breeding.

The advent of the corn show about 1900 and the resulting enthusiastic interest it created in the crop led to the development of two quite different schools of thought on the selection of seed corn. One school regarded the ear as a thing of beauty and more or less assumed that the characteristics associated with its beauty were of value from the standpoint of production. Numerous experiments have indicated that many of the points emphasized by the corn show are not correlated with field performance. The other school placed first emphasis on productiveness and quality and stressed the necessity of field selection of seed ears from standing stalks, resistant to disease. Careful selection which gives due consideration to performance and quality has been amply shown to be of value in varietal improvement.

EAR-TO-ROW SELECTION WIDELY USED BUT DISAPPOINTING

The ear-to-row method of breeding attempted to determine the relative breeding value of different ears by planting a portion of the seed from them, an ear to a row, and measuring the yields of the resulting plots. It was thought that, by selecting seed from the most productive rows or by planting the remaining seed from the highest yielding mother ears and continuing this process for a number of years, the yielding ability of the variety could be improved. The method was introduced by C. G. Hopkins in 1897 at the Illinois Agricultural Experiment Station in experiments to modify the protein and fat content of the corn kernel.

The first results of these investigations were published in 1899, and the method was very generally accepted almost immediately. It had certain difficulties, and modifications were suggested to overcome them. Some of these modifications had to do with the field plot technique of obtaining a reliable yield comparison among the different ear-row plots. Other modifications suggested by Hopkins and his associates and by C. G. Williams, of the Ohio Agricultural Experiment Station, were concerned with preventing inbreeding, and insuring high-yielding parentage on the staminate as well as the pistillate side.

In spite of the fact that the ear-to-row method of breeding seemed to offer great promise when it was first introduced, the results of its use over long periods of time have been disappointing. In general this method of breeding has improved the yields of relatively unselected varieties during the first few years of selection. There was no evidence of cumulative effect, however, and for this reason there has been little to recommend it.

With open pollination the different kernels on an ear are related only through the female side of their parentage. High-yielding mother ears probably owe their yielding ability largely to their female parent, and because of their hybrid nature they split up and lose vigor in the later generations. Any selection toward a single type also introduces a certain amount of inbreeding, which is always associated with reduced vigor in corn.

RESEARCH REVOLUTIONIZES PRODUCTION PRACTICES IN MODERN CORN BREEDING

Modern corn breeding is concerned with the utilization of two breeding methods—mass selection and selection within inbred lines for

the production of hybrid corn. Mass selection still is of value and, when based on selection for performance and quality, probably is the best method for maintaining the yielding ability of open-pollinated varieties adapted to a given region. As already indicated earlier in this article, hybrid corn resulting from the crossing of selected inbred lines is the most recent development in corn-breeding technique and offers greater promise than any of the methods previously tried.[1]

Hybrid corn has been developed as a result of researches in genetics, the science of heredity, and is an outstanding example, perhaps the most outstanding example, of the influence of theoretical scientific research in revolutionizing the production practices of an agricultural crop. Although it is a new development, the hybrids already produced have established their superiority in productiveness and in resistance to wind, disease, and other unfavorable conditions. Hybrid corn may be explained by quoting from Farmers' Bulletin 1744, The What and How of Hybrid Corn.[2]

> Possibly the simplest way to give a general idea of what hybrid corn is, is to compare it to the mule. A corn hybrid, in fact, has many things in common with the mule. A mule is the first-generation hybrid between the mare and the ass, and partakes of the better qualities of both parents. It does not reproduce, but must be produced anew each generation for its value in itself, not for reproduction. A corn hybrid is the first-generation hybrid between two strains of corn. Its value is for seed in the production of a crop of commercial corn. This corn will grow, but cannot be used for seed without a loss in yield in the succeeding generations. A corn hybrid, then, like the mule, must be produced anew each generation for its value in itself, not for reproduction. During that generation good hybrids produce larger acre yields of high-quality corn than do the best commercial varieties. Finally, neither all mules nor all corn hybrids are efficient.

Every experiment station that has distributed hybrid corn has been impressed with the difficulty of convincing growers that seed should not be saved from hybrid plants for future planting. Such advice is so different from previous practice with corn that it seems necessary for each grower to try it at least once and learn from his own experience. The reduction in yield suffered when seed is saved from fields of hybrid corn is greatest for single crosses and progressively less as larger numbers of lines enter the cross. The first hybrids distributed by the Iowa Agricultural Experiment Station were single crosses. The writer still remembers one irate grower who suffered considerable financial loss because he planted some 15 acres with seed he had harvested from his hybrid field and insisted that the warning he had received should have been vigorous enough to make him heed it whether he believed it or not.

Because hybrid corn is new and not generally understood, a number of undesirable practices have developed. Some of them are traceable to this general lack of understanding while others appear to be of a more malicious nature. In an effort to protect the purchaser of hybrid seed corn, several States recently have passed laws defining hybrid corn as the first generation of a cross between strains involving inbred lines and prohibiting the labeling of seed corn as hybrid corn which fails to meet these requirements.

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[1] This method has given outstanding results in the case of sweet corn as well as field corn. Golden Cross Bantam is such a hybrid corn. The discussion of sweet corn, however, must be reserved for a later series of papers dealing with the improvement of vegetables and fruits.

[2] This bulletin may be obtained from the Office of Information, U. S. Department of Agriculture, Washington, D. C.

EARLY WORKERS LAID FOUNDATIONS FOR MODERN BREEDING

The initiation of modern corn breeding may be considered as occurring about 1920, when the inbreeding programs began to get under way, although the foundations were being laid during a period many years earlier.

Six important contributors to early corn improvement are shown in figure 7.[3] One of the most important early breeders was W. J. Beal, professor of botany at Michigan Agricultural College, who began working with corn about 1870. In 1876 he reemphasized the importance of pollen selection in corn improvement, the first mention having been that of Bidwell previously quoted. In 1878 he began experiments with variety crosses which were continued until 1881, when he crossed two varieties by detasseling one of them in what was probably the first detasseled crossing plot. He apparently was the first to hybridize corn for the sole purpose of utilizing the vigor of the first-generation hybrid to increase production. Beal was enthusiastically interested in corn improvement and promoted crossing experiments by other investigators. Notable among these are the Kansas experiments of Kellerman and Swingle and the Illinois experiments of McClure and of Morrow and Gardner.

The idea of using variety crosses did not prove popular, perhaps because of the necessity of producing new crossed seed each year, and although Morrow and Gardner, when their results were published in 1893 and 1894, outlined a plan for farmers to produce their own crossed seed, the method never became established.

Recommendations for the utilization of the excess vigor of first-generation hybrids for commercial corn production were renewed by G. H. Shull in 1908 and 1909, E. M. East in 1909, and G. N. Collins in 1910. Shull and East suggested the crossing of inbred lines while Collins reemphasized the possibilities of increased production from the use of variety crosses.

Previous to 1900 corn had been self-fertilized only occasionally and by very few investigators. In fact, some breeders were of the opinion that corn was self-sterile. About 1900 C. P. Hartley of the Bureau of Plant Industry did some inbreeding, and shortly after that A. D. Shamel produced some inbred lines. In 1905 Shamel reported the yields of two lines which he had selfed for three generations and of the first-generation cross between them, this being the first reported yield of a cross involving inbred lines. Hartley appreciated that increased yields could be obtained from crosses between inbred lines. His inbreeding experiments were discontinued, however, as he considered there were better ways of improving corn than by first tearing it down.

The Work of Shull and East Marks a New Era in Corn Breeding

In 1905 G. H. Shull began inbreeding corn at the Station for Experimental Evolution of the Carnegie Institution of Washington at Cold Spring Harbor, N. Y., in connection with some experiments to study the inheritance of the number of rows of kernels on the ears as influenced by self-pollination and cross-pollination. The performance

[3] A picture of E. M. East, another pioneer in corn breeding, appears in the article on tobacco, p. 824.

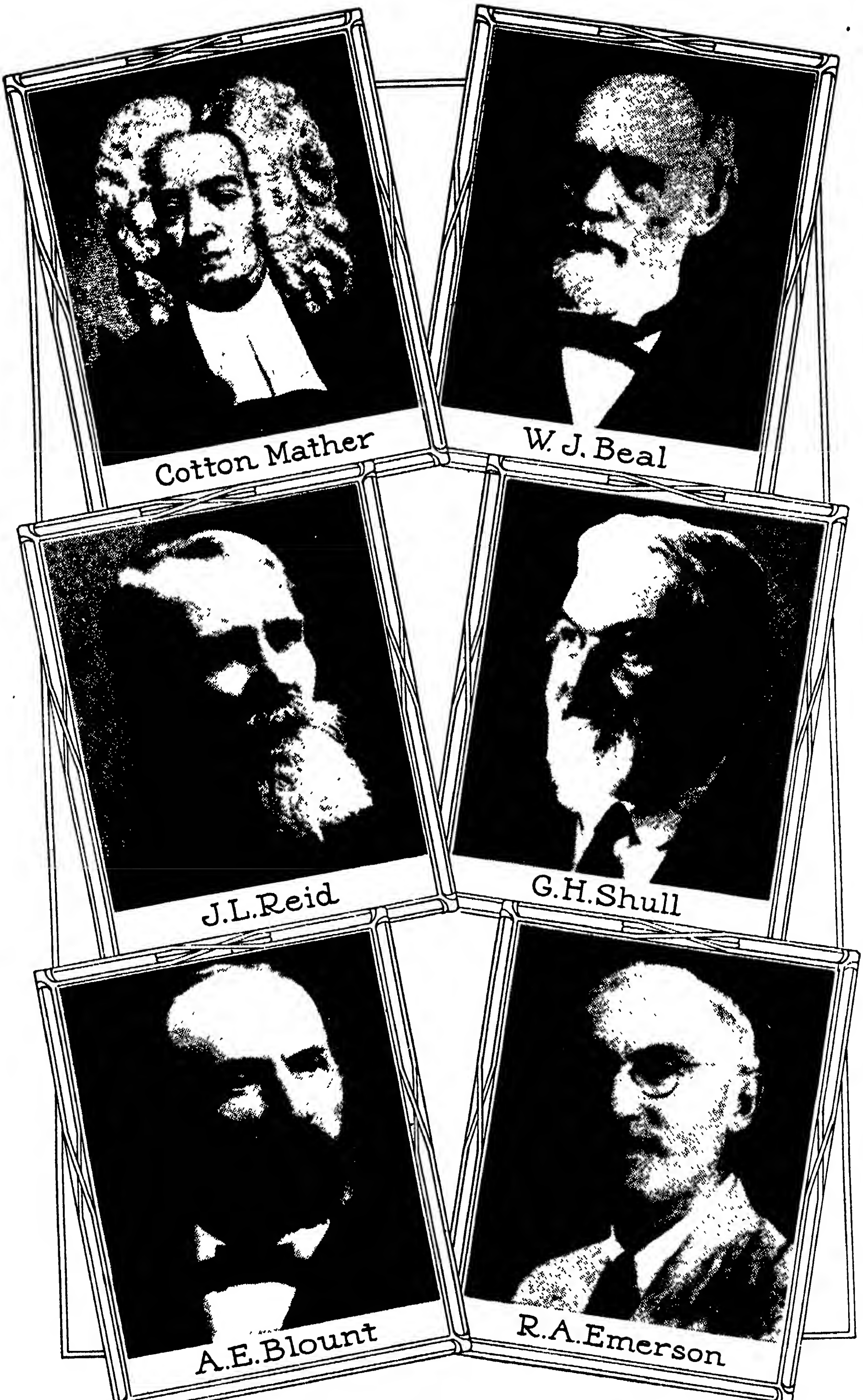


FIGURE 7.—Six pioneers in corn breeding: Cotton Mather, W. J. Beal, J. L. Reid, G. H. Shull, A. E. Blount, and R. A. Emerson.

of the crosses among the inbred lines developed in connection with these studies led to the suggestion of a new method of corn breeding. The publication of these suggestions in 1908 and 1909 marked the beginning of a new era in the breeding of this important crop. Their essential features were: (1) The isolation of desirable inbred lines which breed true for the characters they possess; (2) the determination of which lines are the more productive in crosses; and (3) the utilization of the superior crosses in the commercial production of hybrid corn. Shull's experiments with corn were continued until the end of 1916.

E. M. East also began inbreeding corn in 1905. His experiments were started at the Illinois Agricultural College and continued at the Connecticut Agricultural Experiment Station, where he went in the fall of the year, taking with him the material he had obtained during the season. East's experiments, like those of Shull, were begun for the purpose of studying purely theoretical principles. His investigations had as their primary object an interpretation of the facts to be

HYBRID corn has been developed as a result of researches in genetics, the science of heredity, and is an outstanding example, perhaps the most outstanding example, of the influence of theoretical scientific research in revolutionizing the production practices of an agricultural crop. Although it is a new development, the hybrids already produced have established their superiority in productiveness and in resistance to wind, disease, and other unfavorable conditions.

obtained from a critical study of the effects of inbreeding and outbreeding. His results were reported in a series of publications beginning in 1909, the experiments being continued through 1914.

Other early inbreeding projects were those of G. N. Collins in the Bureau of Plant Industry, begun in 1908, and of E. G. Montgomery, of the Nebraska Agricultural Experiment Station, begun in 1909. In 1914 H. K. Hayes went from Connecticut, where he had been working with East, to the Minnesota Agricultural Experiment Station and began inbreeding corn there. In 1916 F. D. Richey and C. H. Kyle, of the Bureau of Plant Industry, and J. R. Holbert, of Bloomington, Ill., began their inbreeding experiments. H. A. Wallace, of Des Moines, Iowa, the first private breeder to inbreed corn, started his work in 1913 but did not go at it systematically until 1919.

Breeders were rather slow in taking up the new program in an extensive way for several reasons. In the first place, the original suggestion for the use of hybrids among inbred lines contemplated the

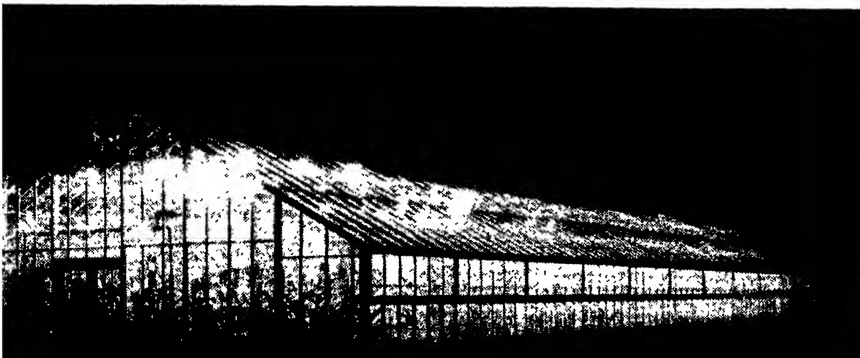
use of single crosses or crosses involving only two inbred lines. There were certain inherent difficulties connected with the use of single crosses which did not make the method seem feasible. It necessitated that the crossed seed be produced on one of the parent inbred lines with a consequent low yield of small seeds which were unsuited for use in ordinary corn-planting machinery. To get around these difficulties, D. F. Jones suggested the use of the double cross, which is the product obtained by crossing two single crosses.

Of greater importance was the delay incident to a more complete investigation of the theory upon which the suggestions were based. It was not until sufficient information on the inheritance of genes affecting qualitative characters had been accumulated, until Emerson and East had advanced a suitable explanation for the performance of quantitative characters, and until the phenomenon of hybrid vigor was better understood genetically, that inbreeding programs began to expand. These developments are discussed in a later section on corn genetics.

Beginning shortly after 1920, there was a very rapid expansion in the number of inbreeding projects. In 1922 F. D. Richey was placed in charge of corn investigations in the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture. He at once began the work of reorganizing and expanding the activities of the Division and coordinating those of the different experiment stations into a more definite national program. In 1925 a committee was appointed to formulate a cooperative program of corn improvement under the Purnell Act, which recently had been passed by Congress. The work of this committee resulted in a plan for a group attack which functioned formally until 1932, and this had an important influence in coordinating the research, in developing a very free interchange of breeding material, and in promoting far more rapid progress than otherwise would have been possible.

Many experiment stations and a few private breeders now are engaged in the isolation and testing of inbred lines in hybrids. Inbreeding projects with corn are being carried on by experiment stations in 33 States and in some foreign countries. A list of the experiment stations in this country at present conducting such inbreeding projects with corn, showing the dates on which the projects were originated, present personnel and former investigators, and the varieties which are being inbred is given in table 2 (p. 499). An attempt

FIGURE 8.—Night view of greenhouse for growing winter crops of corn, showing lights essential in lengthening the day.



was made to obtain similar information on the private breeding projects in this country and on foreign projects, but the data are so incomplete that they are not included.

The improvement of corn through selection in self-pollinated lines necessarily is a slow process, as many generations are required to develop the lines and then to test them in crosses. In an effort to speed up the process, numerous attempts have been made in recent years to obtain two crops a year. The possibilities of growing a winter crop in some of the more frost-free areas of southern Florida, in the Argentine, and in the greenhouse are being investigated. The Bureau of Plant Industry has had very good success raising winter crops of corn in the greenhouse at Arlington Experiment Farm after suitable methods had been developed. It has been found essential to lengthen the day by using electric lights. A night view of the greenhouse used in connection with the corn-breeding investigations of the Bureau, showing the lights for lengthening the day, is given in figure 8.

FIGURE 9.—Young ear shoot protected from stray pollen with a glassine bag.

SEVERAL METHODS USED TO CONTROL POLLINATION

The development of inbred lines and their later use in the production of hybrid corn necessitates controlled pollination. During the inbreeding period and the period of experimental crossing, pollination usually is controlled by hand-bagging of the ears and tassels. In the large-scale production of hybrids, the pollination is controlled by isolation and detasseling.

Self pollination or "selfing" consists in pollinating the silks of selected plants with pollen from the tassels of the same plants. Two quite different methods of accomplishing self-pollination are in common use. Both methods require that the young ear shoot be covered to exclude foreign pollen before the silks emerge. Small glassine bags similar to that shown in figure 9 are very convenient for this purpose. Later operations differ widely for the two methods and will be described separately.

In one procedure, which for convenience may be called the "tassel-bagging method," when the silks appear, the glassine bag is removed, the young shoot is cut back by trimming off the silks and half to three-quarters of an inch of the tips of the husks, and the glassine bag is replaced. The tassel is enclosed in a large bag at this time. In 24 to

48 hours an even brush of fresh silks 1½ to 2 inches long will have grown out. The pollen is collected in the tassel bag and dusted on the silks, and the shoot is again covered with the large tassel bag,

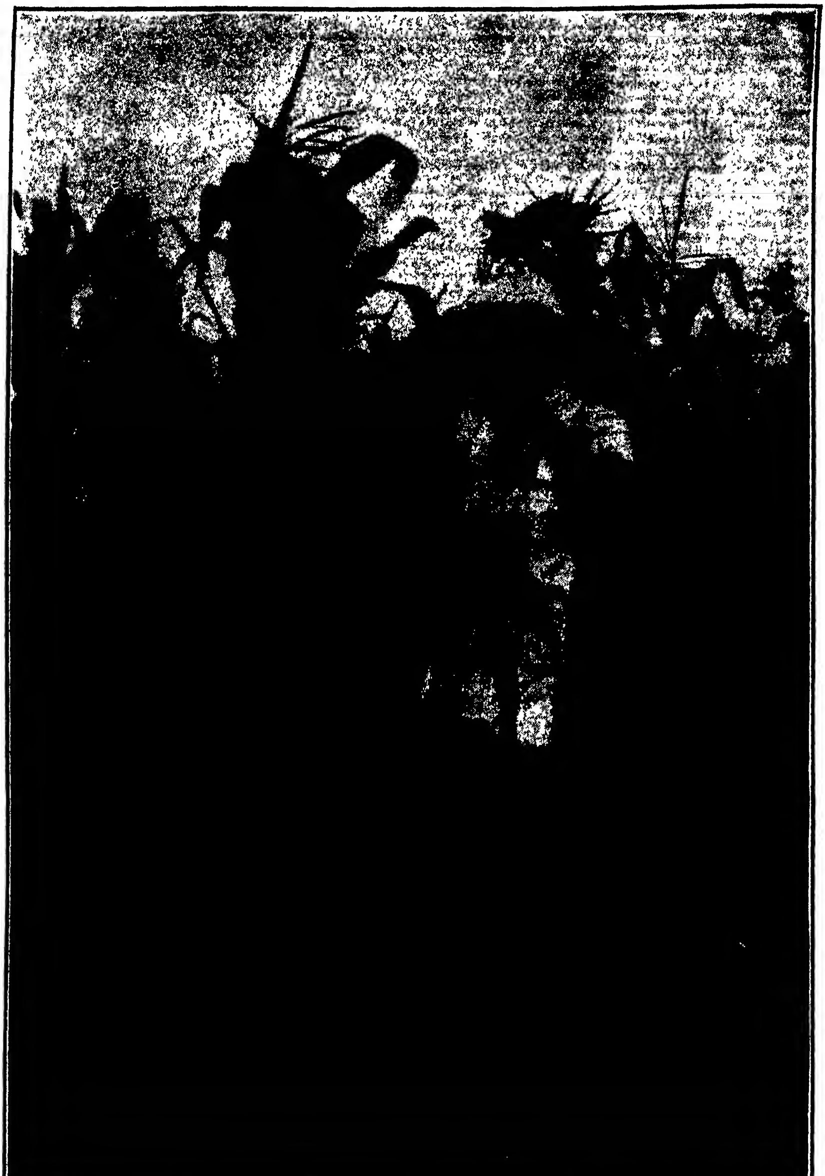


FIGURE 10.—Applying pollen to silks that previously have been protected from stray pollen and will again be protected.

which remains over the ear until harvest. Figure 10 shows pollen being applied to the silks.

A second method, usually designated as the "bottle method," was developed by the writer. When the silks appear under the protect-

ing glassine bag, the bag is removed and the shoot is trimmed back as in the previous method. A 2-ounce bottle of water is hung on the stalk at the ear-bearing node. The tassel is cut from the stalk, its shank is inserted in the bottle of water, and tassel and shoot are enclosed in a large paper bag. The tassel should be arranged directly above the ear shoot. The bottle of water serves to keep the tassel alive while new silks appear, and as fresh silks grow they are pollinated by pollen from the enclosed tassel. It has been found advantageous to use a mild disinfectant in the water to retard the growth

FIGURE 11.—Steps in the bottle method of pollinating: *A*, The glassine bag (shown in fig. 9) has been removed, the silks and tip of the ear shoot cut back and a bottle of water attached to the stalk just above the ear-bearing node; *B*, completed pollination showing shank of tassel inserted in bottle of water.

of micro-organisms and thus lengthen the life of the tassel. A solution of sodium bisulphite 1:2,000, which must be fresh, has proven very satisfactory for this purpose. After 48 to 72 hours the tassels may be removed and the bottles collected. These may be used again for other pollinations. The various steps of the bottle method are illustrated in figure 11.

Several satisfactory methods of hand crossing are in common use. The young shoots must be protected from stray pollen as in selfing

When the silks appear the plants may be crossed in a manner similar to either the tassel-bagging method or the bottle method described above. Where larger quantities of seed are required it is usual to mix the pollen collected from several plants of one line and apply it to

FIGURE 12.—The pollen gun in use: *A*, Pollen gun containing pollen; *B*, gun in use. The end of the gun has been forced into the shoot bag; pressure on the bulb sends a cloud of pollen over the silks.

the silks of the desired number of plants in other lines. For this purpose a pollen gun such as is illustrated in figure 12 is very useful.

The large-scale or commercial production of crossed seed is accomplished by planting alternate blocks of the two parents in a field isolated from other corn and removing the tassels from all of one

FIGURE 13.—An isolated crossing field at the Iowa Agricultural Experiment Station, Ames, Iowa. The tassels have been pulled from the female parent plants growing in four-row blocks, the tassels being left in every fifth row to supply all the pollen in the plot.

kind before pollen has been shed. The seed picked from these detasseled rows is hybrid seed. An isolated field for the production of hybrid seed is shown in figure 13. The ratio of pollen rows to detasseled rows usually varies from 1:2 to 1:4, depending on the vigor and pollen-producing ability of the pollen rows. Where inbred

lines are being crossed the more usual ratio is 1:2, and where single crosses are being crossed to produce double crosses the proportion of pollen rows, under favorable circumstances, may be reduced to 1:4.

CORN BREEDERS UTILIZE MOST INTENSIVE FORM OF INBREEDING

Inbred lines usually are isolated by selfing, the most intensive form of inbreeding. A few lines have been developed by sib pollination, the equivalent of brother-sister mating in animal breeding. T. B. Macaulay, of Montreal, Canada, suggested a method (Journal of Heredity 19: 57–72, 1928) of plot inbreeding, involving sib pollination, which has become known as the Macaulay method. It is being used by a number of investigators in several of the British colonies. The method has certain desirable characteristics but would seem to be less effective than the more intensive form of inbreeding by selfing.

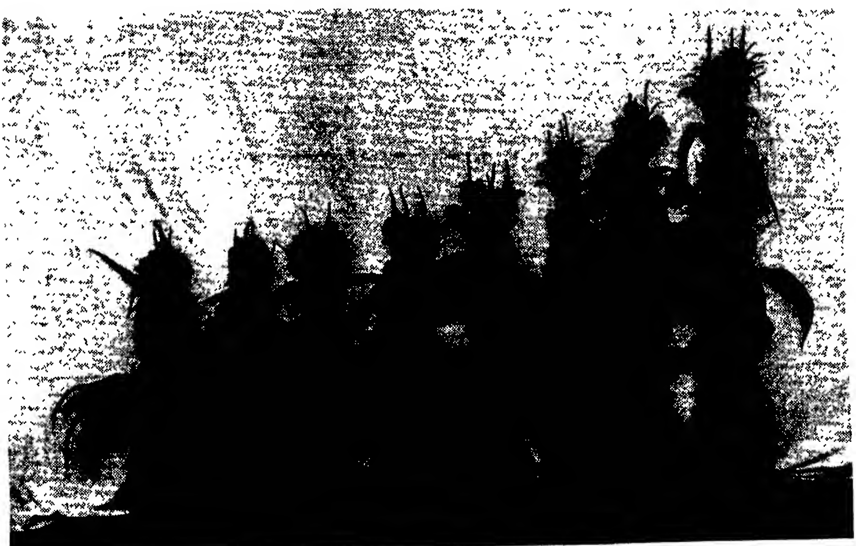


FIGURE 14.—Reduction in vigor as a result of seven generations of inbreeding. (Courtesy Connecticut Agricultural Experiment Station.)

Inbreeding is not an end in itself but only a means to an end. Its purpose is to produce lines which will breed true for the characters they possess. Since corn is naturally cross-pollinated, it is extremely hybrid and unstable. True-breeding lines similar to those in wheat, oats, and barley do not occur naturally but must be produced artificially by many generations of selfing by hand.

In the development of inbred lines, desirable plants of productive varieties are selfed. The resulting ears from the better plants are harvested, and the better of these ears are planted an ear to a row and the good plants again selfed. This process is continued for several generations until the lines thus developed breed true for most of the obvious characters.

Inbreeding in corn always is accompanied by reduction in vigor. It brings to light any defective germ plasm present in the variety

and covered up by the constant crossing which occurs under natural conditions. The reduction in vigor which accompanies inbreeding is greater in the earlier generations of inbreeding and progressively less and less for each generation as inbreeding progresses (fig. 14).

With continued inbreeding there is a marked increase in the uniformity of the plants within lines although there are large differences between lines. Lines with undesirable characters are discarded, and those of most promise are continued. Experience has shown that after five to seven generations of inbreeding, uniformity is attained for most plant characters. Apparently uniformity with regard to yield performance in hybrids is established somewhat earlier. Experience in this respect indicates that after 2 years of inbreeding there is very little segregation for this characteristic.

SIMPLIFYING THE TESTING OF INBRED LINES

Although several experiments have indicated a general correlation between vigor and certain other characters in the parent inbred lines and the productivity of their crosses, these associations are not sufficiently close to be of much assistance in selecting among lines. The relative value of lines in crosses can be determined best by actually using them as the parents of hybrids that are subjected to a careful comparison for relative performance.

The earlier procedures necessitated inbreeding for several generations until the lines were quite uniform. They then were tested in series of comparable single crosses. A more simple procedure widely used at the present time is to make the preliminary crossing trials by using top crosses of the lines with an open-pollinated variety or other heterozygous stock which serves as a tester. The better lines selected from these preliminary comparisons then are subjected to more detailed testing in single crosses, three-way crosses, and double crosses to determine the specific combinations best suited to different locations.

Recent experiments have indicated that the lines attain uniformity with regard to the average yield performance of their hybrids with relatively few generations of inbreeding. Apparently there is little segregation for average yield performance in crosses after two generations of selfing. In fact it is highly probably that a good indication of yielding performance in hybrids may be obtained by testing the top crosses made after the first generation of inbreeding or made with the open-pollinated plant at the time of the first selfing. With the lines reaching relative uniformity for average performance in hybrids after two generations of inbreeding, it is obvious that any selection for this characteristic within lines must be accomplished in either the first or the second generation of inbreeding, preferably in the first, as whatever segregation there is will be greater in this generation.

Although most of the projects listed in table 2 (p. 499) have been under way only a relatively short time, a rather large number of superior inbred lines have been developed and tested. This number should increase rapidly in the future with the recent improvements in breeding technique and in testing procedure, which permit the testing of many more lines. The quality of the lines also should improve materially as the breeding work progresses and new lines are synthesized from those now established or present lines are improved by adding to one line the desirable characteristics of other lines.

The better lines developed in the older breeding projects at the agricultural experiment stations, together with their desirable chacteristics, are given in table 3 (p. 504). Similar information is available on so few of the lines developed by private breeders that they have not been included. . Among the private corn breeders and producers of hybrid corn, a tendency seems to be developing to regard the information they have on their lines and the pedigrees of their hybrids as trade secrets which they are reluctant to divulge. This has interfered with obtaining complete information at the present time. It would seem to be an extremely short-sighted policy, and one that probably will have to be modified in the future when the purchaser of hybrid seed corn demands full information on the nature of the seed he is buying.

PRODUCTION OF HYBRID CORN SEED PROMISES TO BE A LARGE INDUSTRY

The peculiarity of hybrid corn, which restricts its use to the first generation following the cross and requires that new seed be obtained each year, will of necessity result in a considerable industry for the production of this kind of seed. The first hybrid involving inbred lines to be produced commercially was the Burr-Leaming double cross (fig. 15) developed by the Connecticut Agricultural Experiment Station in 1917. The first commercial crossing field for the production of hybrid seed was that of George S. Carter, at Clinton, Conn., used in 1921 for producing crossed seed of Burr-Leaming. About 10 bushels of this seed was sold in the spring of 1922 at $8 per bushel. The first crossing plot for crossing inbred lines by detasseling was on the Connecticut Agricultural Experiment Station farm at Mount Carmel in 1916. This was just 35 years after W. J. Beal in 1881 had grown the first corn in a detasseled crossing plot where two varieties were crossed by detasseling one of them.

The second hybrid to be produced and sold commercially was a single cross between one of the inbred lines of Leaming developed by the Connecticut Agricultural Experiment Station and an inbred line from Chinese Bloody Butcher produced by H. A. Wallace of Des Moines, Iowa. The single cross was developed by Wallace and a small quantity was sold in the spring of 1924 by the Iowa Seed Co. under the name of "Copper Cross."

In 1926 the first seed company was organized for the commercial production of hybrid corn. No appreciable expansion occurred, however, until about 1932, when hybrid-seed production was taken up by several new companies. Since then an increasing number of new concerns have taken up its production each year.

At the present time 44 different hybrids, mostly double crosses, have been released for commercial production from 12 experiment stations. A list of these hybrids, giving their pedigrees, a summary of their performance, and the estimated 1935 acreage of each is shown in table 4 (p. 520). These hybrids are adapted mainly to the Corn Belt and to some of the northern and eastern corn-growing areas. No hybrids suitable for growing in the Southern States have been developed as yet.

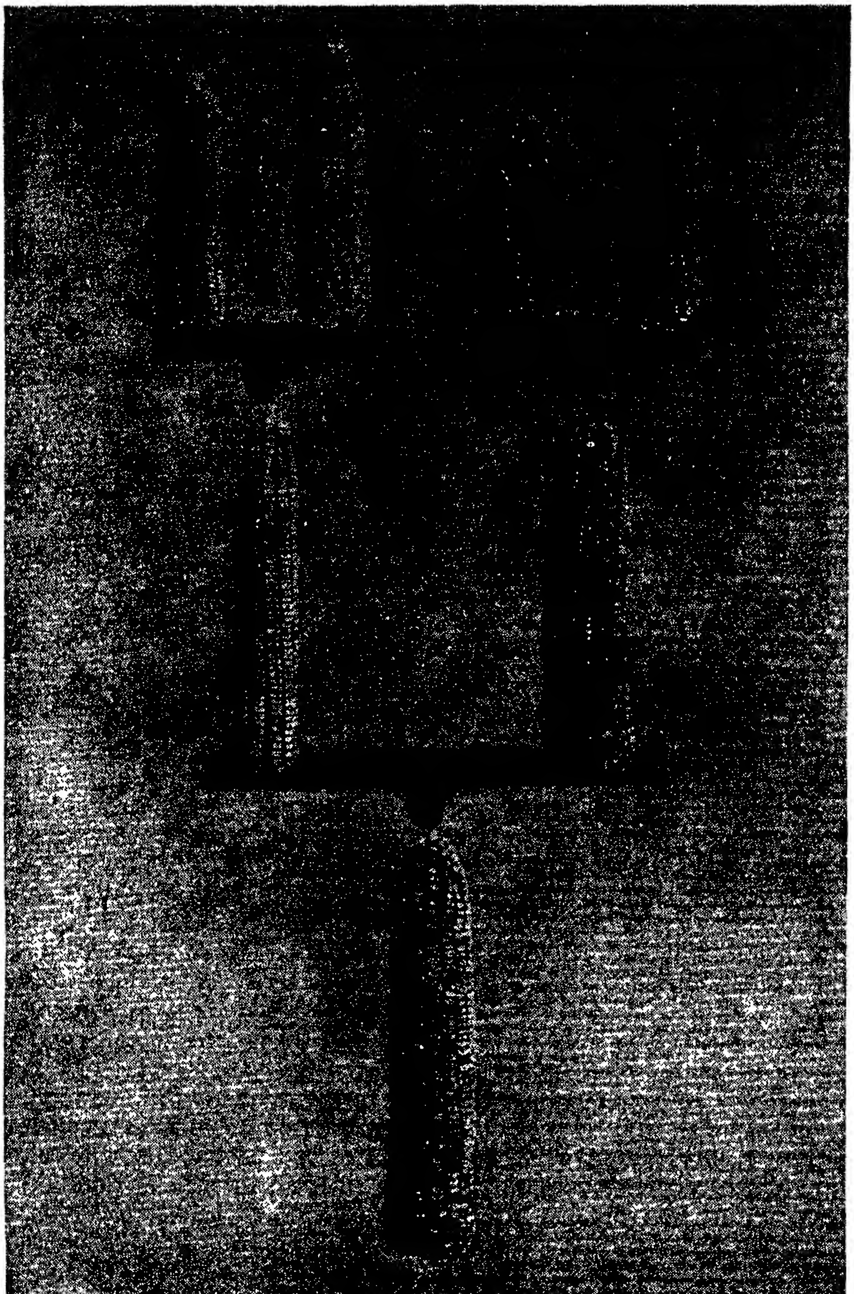


FIGURE 15.—How double-crossed Burr-Leaming was produced. (Courtesy Connecticut Agricultural Experiment Station.)

YIELD INCREASES UP TO 35 PERCENT OVER OPEN-POLLINATED VARIETIES

Corn hybrids are as specific in their adaptation to the soil and climate as open-pollinated varieties and will perform in a satisfactory manner cnly when grown under the conditions to which they are suited. When grown where they are adapted and under favorable environmental conditions, good hybrids may be expected to perform considerably better than open-pollinated varieties. Where the fertility of the soil, the supply of moisture or other external conditions are limiting factors in productivity, however, the increased yields of hybrid corn may not be large enough to make its use economically feasible.

Data from the Iowa Corn Yield Test offer the most extended comparison of the yields of hybrids and varieties. A summary of the

THE hybrids developed up to the present represent only first efforts in the breeding of this kind of corn. Most of the breeding programs are young, and present hybrids unquestionably will be surpassed by the hybrids of the future. In addition, the method offers unusual opportunities for the development of new kinds of corn suited to specific environments or possessing special characteristics. There is every reason to believe that greater progress will be made in corn improvement in the next 25 or 50 years than has been made since the crop came into possession of the white man nearly 450 years ago.

relative yields of hybrids and varieties in 100 district tests extending over the period from 1926 to 1934, inclusive, is shown in table 1, taken from the 1934 report of these tests. As an average of the entire 100 tests, the yield of the hybrids exceeded that of the varieties 9.8 percent. The average annual increases ranged from 6.8 percent in 1927 to 15.2 percent in 1934. The large percentage increase in the extremely unfavorable season of 1934—although actually fewer bushels per acre were produced—is in agreement with similar comparisons from other Corn Belt States and indicates that the hybrids were able to withstand the abnormally dry conditions of that season better than the varieties.

The hybrids that have been distributed for commercial production have given yield increases ranging up to 35 percent, as is shown in table 4. In addition, they show greater resistance to lodging than

the varieties, a consideration which in some cases is of equal or greater importance than the increased yields.

TABLE 1.—*Average yield of hybrid section entries in percentage of the average yield of open-pollinated section entries in the Iowa Corn Yield Test for the years 1926–34*

District no.	1926	1927	1928	1929	1930	1931	1932	1933	1934
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	117.1	109.2	109.8	108.9	114.3	116.2	115.3	114.3	112.4
2	104.6	117.4	120.4	124.1	113.3	--------	101.6	109.5	100.5
3	97.4	102.9	109.3	114.4	110.7	105.9	102.2	107.0	119.4
4	115.5	104.6	110.0	110.1	115.5	111.8	107.2	128.8	111.2
5	106.5	111.1	107.8	108.3	114.4	113.2	108.2	127.6	107.9
6	104.5	109.7	102.8	103.4	104.5	109.0	106.0	116.0	106.0
7	105.3	102.8	113.7	109.1	112.6	107.4	112.0	109.4	--------
8	103.9	98.1	115.3	109.1	123.5	108.4	109.6	114.1	148.7
9	104.9	102.3	113.9	114.1	105.6	106.8	105.5	105.3	115.2
10	111.4	102.2	111.0	107.7	102.3	104.8	102.2	--------	--------
11	102.9	114.3	108.2	112.2	111.4	106.3	110.6	--------	--------
12	110.3	107.1	104.2	106.0	103.2	102.2	99.8	--------	--------
Average	107.0	106.8	110.5	110.6	110.9	108.4	106.7	114.7	115.2

By yielding a profit both to the seed producer and to the commercial corn grower, hybrid corn has demonstrated that it is on a sound basis economically and is here to stay. The hybrids developed up to the present time represent only first efforts in the breeding of this kind of corn. The inbred lines entering into the present hybrids are, in practically all cases, unimproved lines isolated from open-pollinated varieties. Most of the breeding programs are so young that as yet there has been insufficient time to build up and improve existing inbred lines by combining the desirable characteristics of two or more lines into a single line. There is considerable concentration of effort on this phase of the breeding problem at the present time, and present hybrids unquestionably will be surpassed by the hybrids of the future in yield, in resistance to disease and to lodging, and in many other respects.

Hybrid corn offers unusual opportunities for the breeding of kinds suited to specific environments or possessing special characteristics of value to the feeding or milling industries. The investigations in these fields and in others of equal importance are only just begun but offer a great deal of promise. There is every reason to believe that greater progress will be made in corn improvement in the next 25 or 50 years than has been made since the crop came into the possession of the white man nearly 450 years ago.

Genetics Points the Way for Future Development in Breeding

THE corn plant has occupied a leading place in the development of genetic principles. The fact that the ears are large, that controlled fertilization, either self or cross, is accomplished easily, and that a wealth of readily identified, heritable characters of the seed and plant are known, has made corn very attractive for research in both theoretical genetics and practical breeding. An unusually

satisfactory technique for cytological investigations also is available, making the plant admirably suited to research in the border-line field of cytogenetics. It is an extraordinary and fortunate coincidence that this most valuable agricultural crop is so well suited to fundamental studies of breeding and genetics. The result has been a practical breeding program with a quicker response to new developments in theory, and on the other hand a more concerted attack by theoretical genetics on practical breeding problems.

The progress in corn genetics has been so rapid, particularly in the last 20 years, and such a large body of data on the inheritance, interactions, and linkage relations of the many known genes has been accumulated that a detailed review will not be attempted here. The reader interested in more complete information on the subject is referred to A Summary of Linkage Studies in Maize by R. A. Emerson, G. W. Beadle, and A. C. Fraser (Cornell Univ. Agr. Expt. Sta. Memoir 180), which appeared recently. Only sufficient details will be given here, therefore, to acquaint the reader with the broad outline of what has been accomplished.

The original investigations of Gregor Johann Mendel, published in 1866 and lost to the world for 34 years, were conducted with the garden pea. Mendel's experiments and their significance in relation to modern genetics are discussed in the general introduction to this Yearbook. The reader unfamiliar with the few genetic terms which it has been necessary to use in the following pages is referred to the glossary.

Of the three men, H. De Vries, C. Correns, and E. von Tschermak, who independently rediscovered Mendel's laws of inheritance, De Vries and Correns worked with corn. In a sense, therefore, corn shares with peas the honor of being the plant used in the experiments that led to the establishment of Mendel's laws of inheritance.

Between 1825 and 1900 there were many crossing experiments with corn to determine both the immediate effect of the pollen upon such characters as the color and composition of the kernel and also the effect of crossing upon the F_1 (first filial) generation. Outstanding among the workers of this period were E. L. Sturtevant, first director of the New York Agricultural Experiment Station at Geneva, N. Y., W. M. Hays, of the Minnesota Agricultural Experiment Station, and H. J. Webber, in charge of the Plant Breeding Laboratory, Bureau of Plant Industry, United States Department of Agriculture. In 1900 Webber published a paper entitled "Xenia, or the Immediate Effect of Pollen in Maize." This work was done partly in Washington and partly at Lincoln, Nebr., in cooperation with R. A. Emerson, then with the Nebraska Agricultural Experiment Station.

With the rediscovery of Mendel's laws of inheritance in 1900 there immediately began a considerable amount of investigation of the inheritance of specific genes in corn. De Vries and Correns had shown that sugary endosperm was due to the action of a single gene, the sugary condition being recessive to starchy; that is, in crosses between sugary and starchy, the starchy condition prevailed, the sugary condition being suppressed.

From 1902 to 1906 R. H. Lock carried on crossing experiments and inheritance studies with corn in Ceylon. However, his crosses were made in bulk and were thus unsuited to the analysis of segregations involving more than one gene.

In 1911 E. M. East and H. K. Hayes published the results of their work on Inheritance in Maize, conducted at the Connecticut Agricultural Experiment Station. This was by far the most comprehensive investigation of inheritance in corn up to the time of its appearance.

Owing principally to the influence of De Vries, it was at first believed that the different characters of plants and animals were inherited as units. He felt that only the qualitative characters—that is, the characters differing in a "quality" such as color, endosperm texture, and others—followed Mendelian inheritance, while the quantitative characters—those differing in "quantity," as size, height, and others, such as distinguish species—followed some other law of inheritance. It was a significant advance in theory when about 1910 it was suggested that a character was the end product of the action of certain factors or genes and that it was the genes which were inherited as units and not the characters themselves.

In 1913 R. A. Emerson and E. M. East published their work on The Inheritance of Quantitative Characters in Maize. One of the principal stumbling blocks to the general acceptance of Mendelian inheritance was the performance of quantitative characters. Most qualitative characters gave the definite segregation expected on the basis of Mendelian interpretation, but the blending inheritance of quantitative characters did not seem to fit into the same scheme. In a detailed analysis of the inheritance of many quantitative characters in corn, Emerson and East showed that the results were such as "might well be expected if quantitative differences were due to numerous factors inherited in a strictly Mendelian manner." Their findings were influential in promoting a more general acceptance of the Mendelian interpretation of all breeding behavior, and had a very important place in paving the way for the present inbreeding programs. More recently E. W. Lindstrom of the Iowa Agricultural College has shown that genes affecting certain quantitative characters in corn show linkage with genes for qualitative characters. This is to be expected if the two kinds of genes follow the same laws of inheritance.

Genes located on the same pair of chromosomes tend to be transmitted together from parent to offspring and are said to be linked. Historically, the first linkage, then called coherence, reported in corn was that of a gene for aleurone color and the gene for waxy endosperm found by G. N. Collins and J. H. Kempton in 1909 and reported in 1913. In 1918 T. Bregger identified the aleurone factor linked with *wx* to be the *C* factor. Some 30 years previously, however, and 17 years before Mendel's law was rediscovered, E. L. Sturtevant had observed an association between the sugary and pod characters, two characters which since have been shown to be linked.

In the years following the publication of the paper by East and Hayes, extremely rapid progress was made in the study of corn genetics. In 1914 R. A. Emerson left the Nebraska Agricultural Experiment Station to become professor of plant breeding at Cornell University. Emerson and East and their students are responsible for many of the advances made in this work.

The next significant advance in theoretical corn genetics concerned the interpretation of hybrid vigor or heterosis. The phenomenon had been noticed for over a century by plant breeders and probably for at least 2,000 years by animal breeders. The early explanation of the increased vigor of the first-generation hybrids assumed that it was due to the physiological stimulation resulting from the mixing of unlike protoplasm from the egg and sperm. The reduction in vigor with inbreeding was assumed to be due to the disappearance of this stimulation as the strains automatically became pure or homozygous.

In 1910, Bruce, on the basis of purely mathematical considerations, suggested that hybrid vigor might be explained on the basis of the complementary action of favorable dominant growth factors.

Keeble and Pellew in 1910 reported the results of their experiments with peas, which added considerable evidence to support this explanation. They crossed two strains of peas, each 5 to 6 feet tall. One strain had thick stems with many short internodes and the other thin stems and long internodes but fewer of them. The hybrid was 7 to 8 feet in height. In it the characteristic of thick stems with many internodes from one parent was combined with the characteristic of long internodes from the other. The next generation showed segregation into four classes, one class containing plants as tall as the hybrid, two classes containing plants like the two parents, and the fourth class containing dwarf plants which combined the short internodes of one parent with the thin stems and few internodes of the other.

Two serious objections to the complementary action of favorable dominant genes prevented the general acceptance of this explanation of hybrid vigor. If this explanation were correct, then, according to theory, it should be possible with inbreeding to obtain homozygous lines containing the dominant factors contributed by each parent, comparable to the segregates obtained by Keeble and Pellew which had many and long internodes. These lines should be as vigorous as the hybrid and should breed true for their vigor. No such lines of corn have been obtained. Also, as pointed out by Emerson and East, the progeny from crosses exhibiting hybrid vigor should show an unsymmetrical distribution rather than the apparently normal distributions obtained from them.

The suggestion by D. F. Jones in 1917 that linkage between favorable dominant growth factors would account for the failure to meet these two theoretical requirements removed them as objections to this explanation of hybrid vigor and led to its general acceptance. G. N. Collins later has shown that the assumption of linkage probably is unnecessary.

Critical experiments to determine the relative influence of physiological stimulation and of dominant genes in producing hybrid vigor have been extremely difficult to devise. The recent studies of F. D. Richey on convergent improvement seem to offer the best means yet suggested. Richey has suggested a procedure of crossing two lines, backcrossing to each parent through several generations while selecting for the characteristics of the other parent, selfing to fix the factors held by selection, and repeating the process using the improved lines

in order to concentrate or "converge" the favorable genes from the two parent lines into a single line.

If hybrid vigor is due entirely to the action of the dominant genes, these "converged" or recovered lines should be as vigorous as the hybrid between the two parents. If physiological stimulation plays an important role in producing the vigor of hybrids, the recovered lines would be expected to be less vigorous than the hybrid. Incidentally, the method offers much promise as a procedure for improving existing inbred lines.

INHERITANCE OF 350 GENES NOW KNOWN IN CORN

In reviewing the progress in corn genetics, Lindstrom in 1923 estimated that nearly 100 pairs of genes had been isolated and their inheritance determined. Seven of the ten linkage groups had been established at that time. A dozen years later, in 1935, Emerson, Beadle, and Fraser list some 350 genes the inheritance of which is known.

The many genes which have been studied influence such diverse characters of the seed and plant as color of aleurone, endosperm, plumule, scutellum, pericarp, silks, anthers, and leaves; composition of the kernel and plant; chlorophyll development; plant stature; root development; strength of stalk; pollen sterility; sex abnormalities; endosperm and embryo development; branching of the ear and tassel; form of the leaves; development of the silks; rate of pollen-tube growth; carbohydrate metabolism; disease resistance; and even chromosome behavior during cell division.

Most of these characters are simple recessives, a few are dominants, and several of them involve more complex relations among the genes.

All 10 of the linkage groups are now well established, with the locations of from 2 to 10 genes on each rather precisely determined and with less exact data for about 100 additional genes. The 10 linkage groups are shown diagrammatically in figure 16.

The rapid progress in corn genetics during the past 20 years has been promoted, as has been the case in the inbreeding projects, by the hearty cooperation of the research workers, with free interchange of stocks and unpublished data. Beginning about 1920, informal conferences were held from time to time in connection with the winter meetings of the American Association for the Advancement of Science. In 1928, a more formal maize genetics cooperation was developed through the contacts established by the Purnell corn-breeding cooperation previously mentioned and along somewhat similar lines. Its success has been due to the willingness of the workers to cooperate and has been promoted by the efforts of R. A. Emerson, G. W. Beadle, and M. M. Rhodes of Cornell University.

CONDITIONS IN MINUTE CELL CORRELATED WITH BREEDING BEHAVIOR

The corn plant, like every other living organism, whether plant or animal, is built up of minute units called cells. Cytology is the study of cells and cytogenetics may be defined as the correlation of the conditions observed within the cell with genetic data. As the chromosomes, the rod-shaped bodies within the nucleus of the cell, have been established as the bearers of the genes, cytogenetics is concerned

principally with observations on their behavior and the association of peculiarities or variations in this behavior with the data on inheritance.

Early activities of cytologists indicated that the number of chromosomes in corn was not constant for all varieties. The work of L. F. Randolph has shown that this variability arises from the occurrence in certain varieties of supernumerary chromosomes, morphologically unlike the chromosomes of the regular complement. Apparently

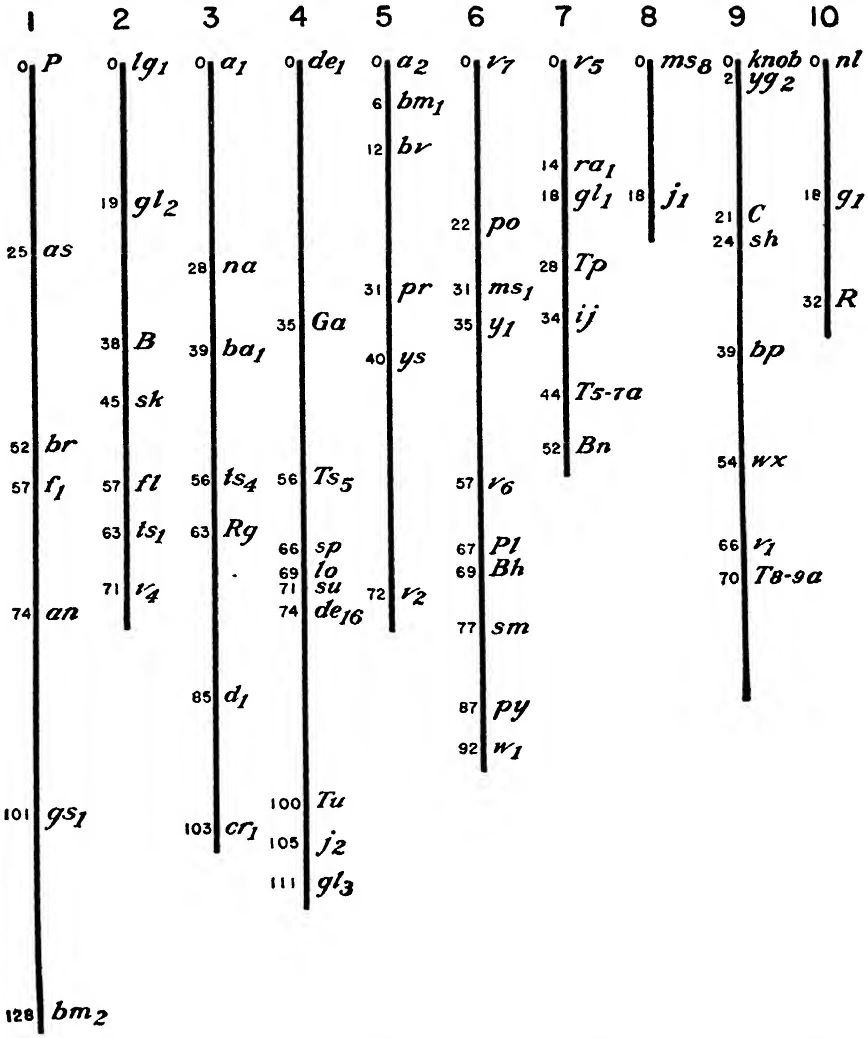


FIGURE 16.—Linkage groups of corn. (Courtesy Cornell University, Agricultural Experiment Station.)

these extra chromosomes carry no hereditary genes, as Randolph has been able to build up stocks having plants with as many as 33 to 35 of them, with only the larger numbers having any apparent genetic effect upon the plant. All varieties of corn have been found to have 10 regular chromosomes, known as the haploid set, in the reproductive cells, 20 in the body cells (10 from the pollen and 10 from the egg),

and 30 in the endosperm cells (10 from the pollen and 10 from each of the two polar nuclei).

In 1925 L. F. Randolph and Barbara McClintock found a 30-chromosome (triploid) corn plant among those being grown for cytological study. This plant had each of the 10 chromosomes of the haploid set present in the body cells in triplicate instead of in duplicate as is the normal condition and was the starting point for determining the association of the genetic-linkage groups with particular chromosomes. The plant was selfed and McClintock was able to obtain a number of individuals among its descendents, each with 1 extra chromosome—that is, 1 of the 10 members of the haploid set was present in triplicate and the other 9 in duplicate. These individuals were studied genetically and cytologically. They were crossed with stocks carrying genes located in the different linkage groups and the genetic ratios determined in the later segregating generations. From their influence upon these ratios, it was possible definitely to associate the extra chromosome with a particular linkage group. Cytological examination determined which one of the 10 chromosomes was present in triplicate. Six of the ten linkage groups were associated in this manner with their respective chromosomes.

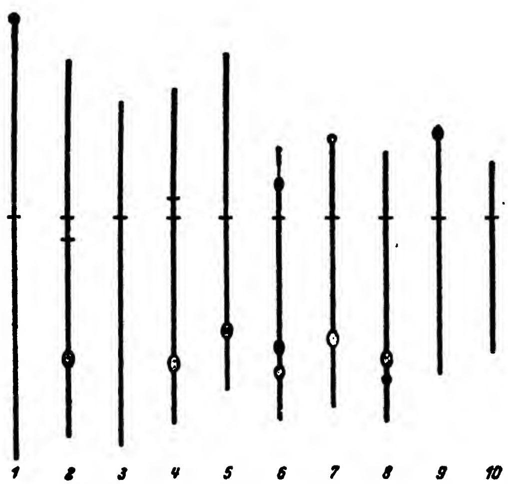


FIGURE 17.—Diagram of the 10 chromosomes of corn. (After McClintock.)

An outgrowth of these investigations was the technique developed by McClintock in 1929 for studying the chromosomes in the early stages of the first nuclear division of the pollen grain. At this time they are in long threads and show the maximum differences among the different members of the haploid set. She was able to identify the different members of the regular complement by their differences in length and general morphology. A diagram of the set is shown in figure 17.

McClintock's technique, and her modifications of it for studying chromosome behavior in early stages of the reduction division previous to the formation of the pollen grains, made corn the outstanding material for cytogenetic investigations. Using this method and stocks containing deficiencies, translocations, and inversions from the radiation experiments of L. J. Stadler, it was possible for the first time to associate particular genes definitely with restricted regions of their respective chromosomes. With the recent appreciation of similar possibilities from investigations of the giant salivary chromosomes of *Drosophila*, the common pomace fly, the facts established in the investigations with corn are being corroborated in this species.

Final association of the last four linkage groups was accomplished through the use of two newer methods. One of them involved the use of mutual translocations between nonhomologous chromosomes, that is, stocks in which an exchange of material had occurred between chromosomes belonging to different pairs. Translocations of this sort result in configurations which may be observed cytologically, and the chromosomes concerned may be identified. They produce semisterility, and through this characteristic they may be used in the same manner as genes and associated with the linkage groups concerned. Through the efforts of C. R. Burnham, R. A. Brink, E. G. Anderson, I. W. Clokey, and others, a sufficient number of interchanges was obtained to associate three of the remaining four linkage groups with their respective chromosomes.

Another new method made it possible to identify the linkage group associated with chromosome 8. When the pollen from a normal corn plant is X-rayed, the chromosomes frequently are broken by the treatment and the fragments often are lost. If this treated pollen is used to pollinate plants carrying recessive genes and the resulting progenies are examined, occasional individuals are found in which the recessive condition has not been suppressed by a dominant allelomorph from the pollen. This situation obtains when the portion of the chromosome containing the dominant allelomorph is broken off as a result of the treatment and lost. If, therefore, these aberrant plants are examined cytologically, it is possible to determine the chromosome that has a fragment missing. The association of chromosome 8, the last chromosome to be associated with its respective linkage group, was accomplished in this manner.

Cytological investigation of corn has proved that crossing over takes place between homologous chromosomes with the physical interchange of chromatic material, as had been predicted on the basis of genetic data. Through these investigations it has been possible to determine that the crossing over is between strands of divided chromosomes rather than between whole chromosomes. It has been found that the chromosomes themselves, while being the bearers of the genes, also are under the control of the genes. Three different genes affecting chromosome behavior were identified by G. W. Beadle. Numerous other discoveries have been made by the cytologists, many of which have an important bearing on genetics and breeding, but these will not be discussed here. The reader is referred to The Cytogenetics of Maize by M. M. Rhoades and Barbara McClintock (The Botanical Review 1: 292–325, 1935) for a more complete review of the subject than is possible here.

MODIFYING GERM PLASM BY LABORATORY METHODS

The discovery by L. F. Randolph of the Bureau of Plant Industry, working in cooperation with Cornell University, of a method whereby the chromosome number of corn plants may be doubled or quadrupled almost at will, without doubt will have a very important influence on future plant breeding. The method involves the application of heat to the young ears at the time of the first divisions of the fertilized egg. Randolph has produced tetraploid corn by this treatment but has found it unstable cytologically. The method, however, offers possi-

bilities for the production of fertile hybrids among species differing in chromosome numbers, an accomplishment impossible by previous methods except as the result of accident.

Radiation with X-rays, radium, and ultraviolet light has been used by L. J. Stadler of the Bureau of Plant Industry, working in cooperation with the Missouri Agricultural Experiment Station, for the artificial production of mutations in corn. Detailed cytological and genetic studies of a large number of the effects of these radiations have demonstrated the principal results to be fragmentation of the chromosomes. The chromosomes are broken and the broken ends often join to give translocations, when a broken end of one chromosome unites with the broken end of a chromosome from a different pair; inversions, when broken ends unite so that a section of the chromosome has been inverted; deficiencies, when sections of the chromosome are lost; and other types of abnormalties. Radiation has been extremely useful in the production of effects helpful in cytological studies and in correlating cytologic and genetic performance. All of the effects so far produced, however, must be considered as defective types. No mutations have been observed that might be considered of practical breeding value.

Some of the Botanical Relatives of the Corn Plant

OUR so-called "crop plants" are too often regarded as belonging to a different category from their "wild" relatives. It may be worth while to remind ourselves that corn is a member of the large and important grass family (Gramineae). This family includes the cereals, the principal food plants of the human race; the millets, important food plants of primitive peoples; many forage plants; sugarcane; sorghum; and the bamboos. The tribe Maydeae, to which corn belongs, is composed of eight genera, five oriental (*Coix*, *Sclerachne*, *Polytoca*, *Chionachne*, and *Trilobachne*) and three American (*Tripsacum*, *Euchlaena*, and *Zea*).

The oriental genera all are native to the region extending from India to Burma through the East Indies and into Australia. Some of the species are widely scattered over this area while others are restricted to very small sections. *Coix* or jobs-tears is the best known member of the group. It consists of a large number of closely related species which are now widely scattered over the warmer sections of the world. Some of the softer shelled varieties are grown as cereals and the hardshelled fruits of others are used for beads.

Among the American genera *Zea* is of greatest importance. It is represented by the single species *Zea mays*, which is Indian corn or maize. All of the cultivated varieties of corn are included in this species and no wild or uncultivated forms are known. Early botanists divided the species *Z. mays* into numerous groups, the classification of Sturtevant being that most widely known. He regarded pod corn as the primitive type and called it *Z. tunicata*. The agricultural types were named as follows: pop corn, *Z. everta;* dent corn, *Z.*

indentata; flour corn, *Z. amylacea;* flint corn, *Z. indurata;* and sweet corn, *Z. saccharata.* Other authorities have preferred to designate these subdivisions as *Z. mays* variety *tunicata, Z. m.* var. *everta,* etc. The present tendency seems to be to regard *Z. mays* as the only species and to designate agricultural varieties by their common names.

Tripsacum or gamagrass (figs. 18 and 19) is represented by one widely distributed species, *T. dactyloides,* which extends throughout the eastern and southeastern part of the United States, the West Indies, and from Mexico to Brazil, and by a number of less widely

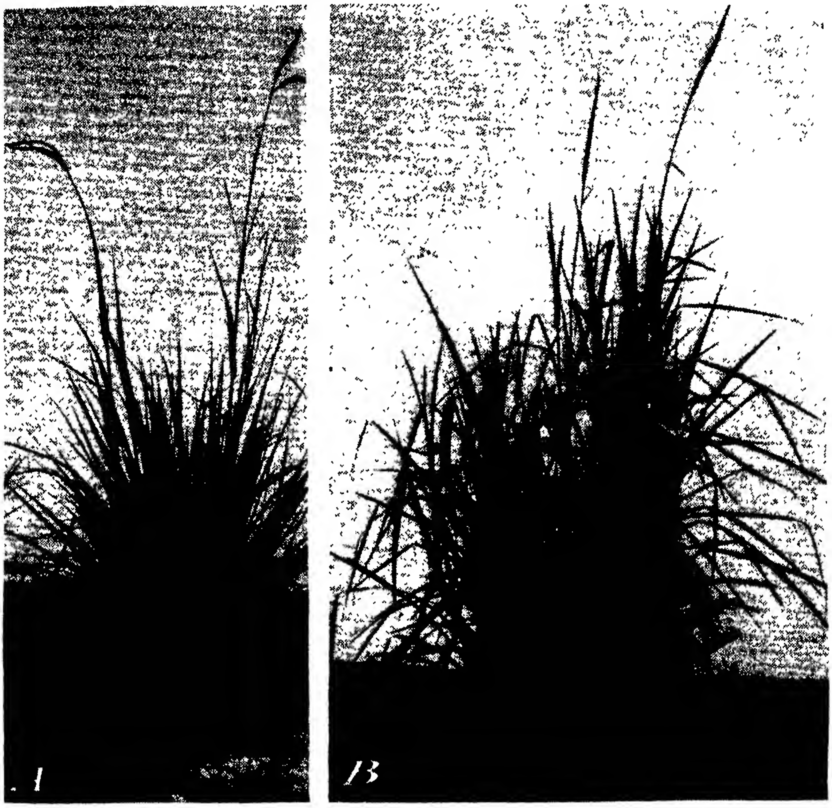


FIGURE 18.—Gamagrass (*Tripsacum dactyloides*) one of the wild relatives of corn: *A*, Diploid form from Texas with 36 chromosomes; *B*, tetraploid form from Connecticut with 72 chromosomes. (Courtesy Journal of Heredity.)

distributed species. Two forms of *T. dactyloides* are known, one a diploid form with 18 pairs of chromosomes and the other a tetraploid with 36 pairs. The species has some value as a forage plant but none as a grain crop and probably never was used as a food plant by the Indians.

Euchlaena, commonly called teosinte (fig. 2) is without question the closest wild relative of corn. It is a native of southern Mexico and Guatemala, where it often occurs at the present time as a weed along the margins of cornfields. Two forms of teosinte are known, one being an annual (*E. mexicana*) and the other a perennial (*E.*

perennis). Perennial teosinte has 20 pairs of chromosomes, twice the number present in annual teosinte, and possibly may be the tetraploid form of the annual, inasmuch as L. F. Randolph has been able to produce a perennial from the annual by a treatment which doubled the chromosome number. The annual is by far the most common, the perennial having been found only in a very restricted area in Jalisco, Mexico. Annual teosinte has been used frequently as a forage plant, but as the seeds are enclosed in an extremely horny covering it is of no value as a grain crop.

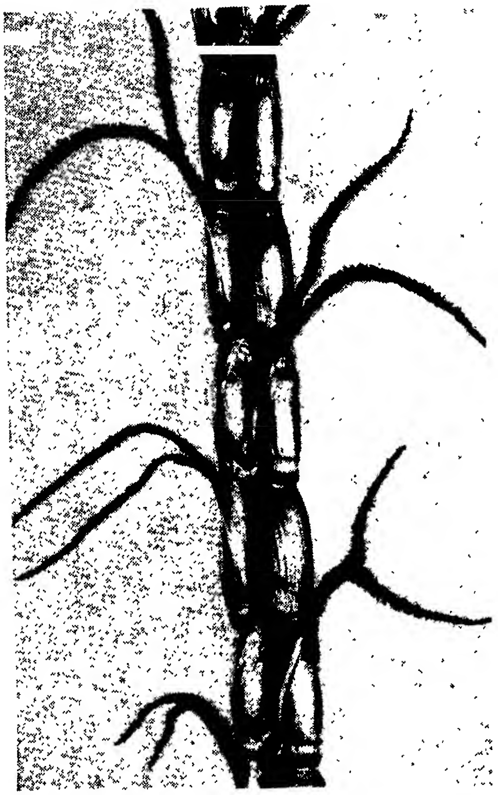


FIGURE 19.—Pistillate inflorescence of diploid gamagrass. (Courtesy Journal of Heredity.)

HYBRIDS OF CORN WITH RELATED PLANTS

Corn has been crossed with two related genera, teosinte and gamagrass. Corn crosses readily with each of the three annual strains of teosinte, commonly referred to as the Chalco, Durango, and Florida forms, and the F_1 plants are fertile. The hybrid is illustrated in figure 20. In sections of Mexico and Central America annual teosinte occurs as a weed in the margins of cornfields and there is so much natural crossing with corn that pure seed of teosinte often is difficult to obtain. It is highly probable that the teosinte stock obtained by Luther Burbank, from which he stated he had developed corn after 18 years of selection, was in fact a corn-teosinte hybrid when the selection was begun.

Crosses of corn with annual teosinte have been studied genetically and cytologically and the chromosomes of the two genera found to be very similar. The amount of crossing over is essentially of the same order as in corn for all regions that have been tested, with the exception of the short arm of chromosome 9 in the Durango and Florida hybrids, where no crossing over occurs.

Crosses have been made between corn and perennial teosinte. Both fertile and sterile hybrids have been obtained. These hybrids also have been studied cytologically and genetically but not extensively.

In the fertile hybrids, crossing over has been found to occur between the chromosomes of corn and their homologs from the perennial teosinte.

By using a special technique P. C. Mangelsdorf and R. G. Reeves of the Texas Agricultural Experiment Station succeeded in crossing gamagrass with corn. The F_1 hybrids of corn with diploid gamagrass (18 pairs) have 28 chromosomes which do not pair. They are slightly fertile on the female side, as is shown by backcrossing, but are completely male sterile. The F_1 hybrids of corn with tetraploid gamagrass (36 pairs) have 46 chromosomes, among which the 36 gamagrass chromosomes pair to give 18 bivalents and the 10 corn chromosomes are left as univalents. These F_1 plants are both male and female sterile. Representative plants of the hybrids of corn with gamagrass are shown in figure 21. The F_1 hybrid of corn with diploid gamagrass has been crossed with annual teosinte and a trigeneric hybrid obtained containing chromosomes from corn, gamagrass, and teosinte (fig. 22). Numerous attempts have been made to cross corn with others of its close relatives. So far as is known these attempts have not been successful.

FIGURE 20.—The first-generation hybrid of corn × annual teosinte. (Courtesy Texas Agricultural Experiment Station.)

New Concepts May Lead to Still Greater Changes in Corn Breeding

THE genetic research already conducted on corn and other organisms has contributed materially to the extension of our knowledge of the mechanism of heredity. It forms the basis on which practical breeding methods are formulated and is solely responsible for the development of present corn-breeding methods. This research, however, is still in the beginning stages and it may be expected that

through further progress breeding methods will improve still more. It is possible that new and entirely different methods of inheritance may be discovered.

Investigations up to the present time have indicated the possibilities that may be expected in the future. They have demonstrated that it is possible to obtain inbred lines which differ in resistance to disease, insects, cold, drought, and lodging, composition of the plant and grain, and productivity. Practically nothing has been accomplished as yet, however, in transferring these desirable qualities from one line to another, thus making it possible to improve existing lines. All show quantitative inheritance and are difficult, though by no means impossible, to manipulate from the breeding standpoint.

FIGURE 21.—First-generation hybrids of corn with gamagrass: *A*, 28-chromosome hybrid of corn × diploid gamagrass; *B*, 46-chromosome hybrid of corn × tetraploid gamagrass. (Courtesy Texas Agricultural Experiment Station.)

From the standpoint of the more immediate demands of practical corn improvement, there is need for more information on the inheritance of all characters, particularly quantitative characters, to give a better basis for the synthesis of lines and varieties with desirable characters. More should be known about the nature of hybrid vigor and the possibilities of developing high-yielding inbred lines or of synthesizing varieties that will remain stable. Methods should be developed, if possible, for producing homozygous lines without resorting to the tedious procedure of inbreeding. Any specific genes which contribute to the physiological or morphological resistance to disease, cold, drought, and insect damage should be isolated if possi-

ble and the nature of their action determined. In order that strains of greater value to the feeding and milling industries may be developed, more information must be gathered on the inheritance and action of the genes controlling the vitamin, carbohydrate, protein, amino acid, and mineral content of the plant and grain.

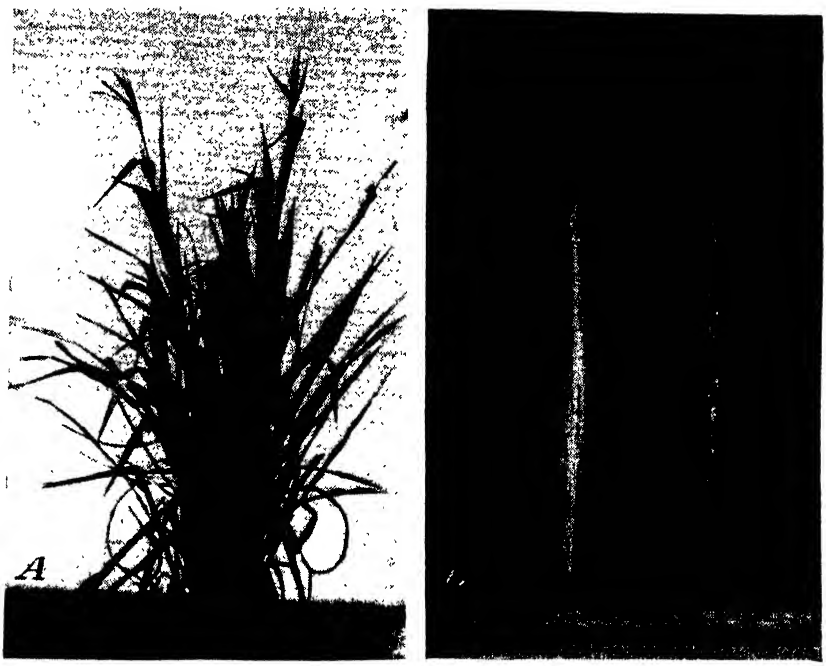


FIGURE 22.—Trigeneric hybrid of (corn × diploid gamagrass) × annual teosinte: *A*, Plant; *B*, "ears". (Courtesy Journal of Heredity.)

From the standpoint of theory, greater knowledge is needed of the nature and properties of the genes and the nature and origin of gene changes. Of interest also are the factors contributing to the origin of new species.

The solution of these problems may open up new concepts which may introduce still more drastic changes in our corn-breeding methods than those that recently have taken place.

Appendix

List of Corn Varieties Recommended in the Different States by Their Respective Experiment Stations

Alabama:
- Cocke Prolific
- Douthit Prolific
- Hastings Prolific
- Indian Chief
- Locker Yellow
- Mosby Prolific
- Neal Paymaster
- Whatley Prolific

Arizona:
- Bloody Butcher
- Colorado 13
- Cream Dent
- Cridebring Yellow Dent
- Duncan White Dent
- Golden Republic
- Lawson White Dent
- Mexican June
- Minnesota 13
- Pennsylvania Sweepstakes
- Reid Yellow Dent
- Santa Cruz Yellow Dent
- Smith Yellow Dent
- Swadley
- 4 × Yellow Dent

Arkansas:
- Champion White Pearl
- Cocke Prolific
- Delta Prolific
- Golden Standard Leaming
- Goliad
- Hastings Prolific
- Huffman
- Johnson County White
- Leaming
- Marlboro Prolific
- Mexican June
- Mosby Prolific
- Neal Paymaster
- Pride of Saline
- Reid Yellow Dent
- St. Charles White
- Southern Beauty
- Surcropper
- Valentine Yellow Dent
- Weekley Prolific
- White Wonder

California:
- King Philip Hybrid

Colorado:
- Colorado 13
- Crawford Yellow Flint
- Iowa Silvermine
- Minnesota 13
- Reid Yellow Dent

Connecticut:
- Canada Yellow Flint
- Century Dent
- Lancaster Surecrop
- West Branch Sweepstakes

Delaware:
- Boone County White
- Funk Yellow Dent
- Johnson County White
- Lancaster Surecrop
- Leaming
- Reid Yellow Dent

Florida:
- Cuban Yellow Flint
- Dubose
- Good Golden Prolific
- Tisdale
- Tuxpan
- Whatley Prolific
- Wilson Yellow Dent

Georgia:
- Hastings Prolific
- Piedmont Two-Ear
- Whatley Prolific

Idaho:
- Minnesota 13
- Northwestern Dent
- Reid Yellow Dent
- Rustler White Dent
- Silver King

Illinois:
- Black Hawk
- Boone County White
- Canterbury Yellow Dent
- Champion White Pearl
- Eversole White Dent
- Funk 176A
- Golden Beauty
- Krug
- McKeighan Yellow Dent
- Moore Yellow Dent
- Mountjoy Utility Dent
- Sommer Yellow Dent
- Station Yellow Dent
- Steigelmeier Yellow Dent
- Western Plowman
- Will County Favorite

Indiana:
- Clarage
- Clement White Cap
- Johnson County White
- Krug

Indiana—Continued.
- M. A. C. Yellow Dent
- Reid Yellow Dent
- Troyer Yellow Dent
- Woodburn Yellow Dent

Iowa:
- Beary Yellow Dent
- Black Yellow Dent
- Chantland Yellow Dent
- Clampitt Yellow Dent
- Feldman Yellow Dent
- Four County White
- Golden King
- Harkrader Yellow Dent
- Kossuth Reliance
- Krug
- Meyer Yellow Dent
- McCulloch Yellow Dent
- Osterland Yellow Dent
- Reid Yellow Dent
- Rupp Early Yellow Dent
- Silver King
- Smith Yellow Dent
- Steen Yellow Dent
- Walden Dent
- Wilson Yellow Dent
- Wimple Yellow Dent

Kansas:
- Cassel White Dent
- Colby Yellow Cap
- Freed White Dent
- Hays Golden
- Harmon White
- Kansas Sunflower
- Midland Yellow Dent
- Pride of Saline
- Reid Yellow Dent

Kentucky:
- Boone County White
- Johnson County White
- Leaming
- Neal Paymaster
- Pride of Saline
- Reid Yellow Dent
- St. Charles White
- Tennessee Red Cob

Louisiana:
- Cocke Prolific
- Creole Yellow Flint
- Hastings Prolific
- Hill Yellow Dent
- Imperial White
- Sentell White Dent

List of Corn Varieties Recommended in the Different States by Their Respective Experiment Stations—Continued

Maine:
- Ashmont Golden Flint
- Early Canada Flint
- Longfellow Flint

Maryland:
- Boone County White
- Golden Queen
- Johnson County White
- Reid Yellow Dent
- Sure Crop

Massachusetts:
- Burwell Yellow Flint
- Canada Yellow Flint
- Cornell 11
- Davis Yellow Flint
- Early Huron
- Golden Glow
- Gold Nugget
- King Philip Flint
- Longfellow Flint
- Rhode Island White Flint
- Rustler White Dent
- Sanford White Flint
- Sheffield Yellow Flint
- Williams Yellow Dent

Michigan:
- Clement White Cap
- Duncan
- Ferden Yellow Dent
- Golden Glow
- King Philip Flint
- Longfellow Flint
- M. A. C. Yellow Dent
- Northwestern Dent
- Pickett
- Polar Dent
- Wisconsin 25

Minnesota:
- Dakota White Flint
- Gehu Yellow Flint
- Golden Jewel
- Golden King
- Minnesota 13
- Minnesota 23
- Murdock
- Northwestern Dent
- Pearl White Flint
- Rustler White Dent
- Silver King

Mississippi:
- Cocke Prolific
- Hastings Prolific
- Jarvis Golden Prolific
- Laguna
- Mexican June
- Mosby Prolific
- Neal Paymaster

Missouri:
- Boone County White

Missouri—Continued.
- Commercial White
- Krug
- Midland Yellow Dent
- Reid Yellow Dent
- St. Charles White
- St. Charles Yellow
- 110 Day

Montana:
- Brown County Yellow Dent
- Dakota White Flint
- Falconer Semi-dent
- Gehu Yellow Flint
- Minnesota 13
- Minnesota 23
- Northwestern Dent
- Pioneer White Dent
- Rustler White Dent
- Silver King

Nebraska:
- Blair White
- Boone County White
- Cattle Corn
- Johnson County White
- Krug
- Leaming
- Minnesota 13
- Reid Yellow Dent
- Silvermine
- St. Charles White

Nevada:
- Minnesota 13
- Wisconsin 25

New Hampshire:
- Canada Flint
- Cornell 11
- Early Leaming
- Gold Nugget
- King Philip Flint
- Longfellow Flint
- Minnesota 13
- New Hampshire 500
- Sanford White Flint
- West Branch Sweepstakes.
- Also numerous local strains of flint and a few of dent.

New Jersey:
- Hulsart Yellow Dent
- Lancaster Surecrop
- Mercer White Cap
- Reid Yellow Dent
- Somerset Leaming

New Mexico:
- Bloody Butcher
- Delta Prolific
- Hastings Prolific
- Mexican June

New York:
- Angel of Midnight
- Cornell 11
- Cornell 11, early strain
- Golden Glow
- King Philip Flint

North Carolina:
- Biggs Two-Ear
- Cocke Prolific
- Dixie
- Golden Queen
- Highland Horsetooth
- Highland King
- Holcombe Prolific
- Indian Chief
- Jarvis Golden Prolific
- Latham Double
- Silvermine
- Southern Beauty
- Weekley Improved

North Dakota:
- Dakota White Flint
- Falconer Semi-dent
- Gehu Yellow Flint
- Ivory King
- Mercer Flint
- Minnesota 13
- Northwestern Dent
- Payne White Dent
- Pioneer White Dent
- Rustler White Dent

Ohio:
- Clarage
- Cook
- Johnson County White
- Leaming
- Medina Pride
- Reid Yellow Dent
- Scioto County White
- Waugh
- Woodburn Yellow Dent

Oklahoma:
- Ferguson Yellow Dent
- Mexican June
- Midland Yellow Dent
- Oklahoma Silvermine
- Reid Yellow Dent
- Southwestern Yellow Dent
- Surcropper

Oregon:
- Golden Glow
- Golden King
- Minnesota 13
- Reid Yellow Dent
- Silvermine

Pennsylvania:
- Clarage
- Early Butler
- Golden Glow

List of Corn Varieties Recommended in the Different States by Their Respective Experiment Stations—Continued

Pennsylvania—Contd.
- Golden Queen
- Lancaster Surecrop
- Leaming
- West Branch Sweepstakes
- White Cap (several varieties)

Rhode Island:
- Rhode Island White Flint

South Carolina:
- Douthit Prolific
- Garrick Prolific
- Goodman Prolific
- Hastings Prolific
- Lowman Yellow
- Marlboro Prolific
- Neal Paymaster
- Pee Dee No. 5

South Dakota:
- All Dakota
- Alta
- Eureka
- Fulton Yellow Dent
- Minnesota 13
- Northwestern Dent
- Reid Yellow Dent
- Silver King (Wisconsin 7)
- Wimple Yellow Dent

Tennessee:
- Jarvis Golden Prolific
- Jellicorse
- Neal Paymaster
- Thompson Prolific

Texas:
- Bloody Butcher
- Chisholm
- Davis Prolific
- Ferguson Yellow Dent
- Gorham Yellow Dent
- Hastings Prolific
- Horton
- Mexican June
- Mosshart Yellow Dent
- Oklahoma White Wonder
- Reese Drought Resister
- Strawberry
- Surcropper
- Thomas
- Tuxpan
- Virginia White Dent

Utah:
- Australian White Flint
- Falconer Semi-dent
- Improved Leaming
- Mercer Flint
- Minnesota 13
- Northwestern Dent
- Pride of Saline
- Reid Yellow Dent

Vermont:
- Canada Leaming
- Cornell 11
- Davis Flint
- Minnesota 13
- West Branch Sweepstakes

Virginia:
- Boone County White

Virginia—Continued.
- Casey Purebred
- Golden Queen 5
- Highland King
- Reid Yellow Dent
- Virginia White Dent

Washington:
- Reid Yellow Dent
- Thayer Yellow Dent
- Windus White Dent

West Virginia:
- Boone County White
- Golden Glow
- Johnson County White
- Lancaster Surecrop
- Leaming
- Reid Yellow Dent
- Shoe Peg
- Silver King
- Woodburn White Dent

Wisconsin:
- Golden Glow
- Minnesota 13
- Murdock
- Northwestern Dent
- Silver King
- Wisconsin 8
- Wisconsin 25

Wyoming:
- Australian White Flint
- Falconer Semi-dent
- Gehu Yellow Flint
- Minnesota 13
- Northwestern Dent
- Pride of the North
- Yellow Flint

TABLE 2.—*Location of projects on corn improvement based on selection in inbred lines*

State, institution, and location	Date begun	Present personnel	Former investigators	Varieties included
Arizona:				
Bureau of Plant Industry, Division of Genetics and Biophysics:				
United States Field Station, Sacaton.	1918	G. N. Collins, J. H. Kempton		Sacaton June.
Arkansas:				
Agricultural Experiment Station, Fayetteville.	1923	C. K. McClelland	L. W. Osborn	Funk 90-day, Mexican June, Reid Yellow Dent, Valentine Yellow Dent, Biggs Seven-Ear, Whatley Prolific, Jarvis Golden Prolific, Neal Paymaster.
California:				
Agricultural Experiment Station, Berkeley.	1928	W. W. Mackie, F. L. Smith		King Philip Hybrid, Hopi White Flour.
Colorado:				
Agricultural Experiment Station, Fort Collins.	1920	Warren H. Leonard, J. J. Curtis, Dwight Koonce.		Pride of the North, Minnesota 13.
Connecticut:				
Agricultural Experiment Station, New Haven.	1905	D. F. Jones, W. R. Singleton, L. C. Curtis.	E. M. East, H. K. Hayes	Burr White, Illinois Leaming, Illinois High Protein, Illinois Low Protein, Stadtmueller Leaming.
Florida:				
Agricultural Experiment Station, Gainesville.	1927	Fred H. Hull, W. A. Carver, J. D. Warner, A. Daane.		Tisdale, Wilson Yellow Dent, Whatley Prolific, Cuban Yellow Flint, Dubose, Hastings Prolific, Gist, Garrick Prolific, Neal Paymaster, Delta Prolific, Kilgore, Red Cob Prolific.
Georgia:				
Agricultural Experiment Station, Experiment.	1924	R. P. Bledsoe, S. J. Hadden		Whatley Prolific, Garrick Prolific, Delta Prolific, Steinheimer.
Coastal Plain Experiment Station, Tifton.[1]	1929	C. H. Kyle, H. S Garrison		Garrick Prolific, Whatley Prolific, Cuban Yellow Flint, Creole Yellow Flint, Silver King, Boone County White.
Idaho:				
Agricultural Experiment Station, Moscow.	1934	C. A. Michels		Leaming (6 local strains).
Illinois:				
Agricultural Experiment Station, Urbana.[1]	1921	C. M. Woodworth, W. J. Mumm, G. H. Dungan, A. L. Lang, J. H. Bigger, W. D. Flint, E. E. DeTurk, Ben Koehler.		Reid Yellow Dent, Illinois High Yield, Illinois High Oil, Moore Yellow Dent, Illinois Two-Ear, Long John.
Bureau of Plant Industry, Division of Cereal Crops and Diseases:				
United States Corn Field Experiments, Bloomington.[2]	1916	J. R. Holbert, Boyd Frye, J. W. Hardin.		Funk Yellow Dent, Krug, Mann Leaming, 90-Day, Illinois High Yield, Illinois Two-Ear, Illinois Low-Ear, Griffin Yellow Dent, Western Plowman, Golden Beauty, Democrat, Eastern Illinois Utility.

TABLE 2.—*Location of projects on corn improvement based on selection in inbred lines*—Continued

State, institution, and location	Date begun	Present personnel	Former investigators	Varieties included
Indiana:				
Agricultural Experiment Station, Lafayette.[1]	1919	R. R. St. John, J. F. Trost	G. N. Hoffer, B. H. Duddleson	Reid Yellow Dent, Johnson County White, Crawford, Silver King, Leaming, Krug, Golden Glow, Woodburn Yellow Dent, Funk Yellow Dent, Calico.
Iowa:				
Agricultural Experiment Station, Ames.[1]	1922	Farm crops section: A. A. Bryan, H. D. Hughes, M. M. Rhoades, R. W. Jugenheimer, J. L. Robinson, J. A. Rigney. Genetics section: E. W. Lindstrom, E. J. Wellhousen, K. Kopf.	M. T. Jenkins, L. C. Burnett	Four County White, Silver King, United States Selection 133, Iodent, Lancaster Surecrop, Black Yellow Dent, Proudfit Yellow Dent, Krizer Bros. Yellow Dent, McCulloch Yellow Dent, Osterland Yellow Dent, Clark Yellow Dent, Walden Dent, Argentine Flint, Western Flint, Rainbow Flint, Krug, Rupp Yellow Dent, Meyer Yellow Dent.
Kansas:				
Agricultural Experiment Station, Manhattan.[1]	1922	A. M. Brunson	J. H. Parker, J. G. Willier, C. W. Bower.	Pride of Saline, Freed White Dent, Colby Bloody Butcher, Kansas Sunflower, Illinois High-Yield, Illinois Two-Ear, Hays Golden, Blue Squaw, Yellow Selection No. 1, Midland Yellow Dent, Reid Yellow Dent, Illinois Low-Ear.
Kentucky:				
Agricultural Experiment Station, Lexington.	1921	E. J. Kinney		Boone County White, Reid Yellow Dent, Iowa Silvermine, Pride of Saline, Neal Paymaster.
Louisiana:				
Agricultural Experiment Station, Baton Rouge.[1]	1923	Hugo Stoneberg		Cocke Prolific, Mosby Prolific, Hastings Prolific, Whatley Prolific, Delta Prolific, Tisdale, Clovelly, Creole Yellow Flint.
Maryland:				
Agricultural Experiment Station, College Park.	1922	J. E. Metzger, W. B. Kemp, R. G. Rothgeb, I. M. Goss.		Reid Yellow Dent, Johnson County White, White Cap.
Michigan:				
Agricultural Experiment Station, East Lansing.	1923	J. R. Duncan, A. R. Marston	E. E. Down, K. M. Liu	Duncan Yellow Dent, Golden Glow, Northwestern Dent, Pickett, Clement White Cap, Wisconsin Cold Resistant Golden Glow, Wisconsin No. 25, Polar Dent, M. A. C. Yellow Dent, Dent du Cheval, Longfellow Flint, King Philip Flint, Maize Amargo.
Minnesota:				
Agricultural Experiment Station, University Farm, St. Paul.	1914	H. K. Hayes, I. J. Johnson, C. W. Doxtator.	T. B. Hutcheson, P. J. Olson	Minnesota 13, Rustler White Dent, Northwestern Dent, Minnesota 23, Silver King, Golden King, Golden Glow, Longfellow Flint, King Philip Flint, Squaw Flint.

Mississippi: Agricultural Experiment Station, State College.	1918	J. Fred O'Kelly, C. R. Owen	H. B. Brown	Mosby Prolific, Laguna, Cocke Prolific, Hastings Prolific, Goliad, Neal Paymster, Golden Dent, Yellow Dent, Hickory King, Surcropper, Jellicorse.
Missouri: Agricultural Experiment Station, Columbia.[1]	1922	L. J. Stadler, G. F. Sprague	R. T. Kirkpatrick, W. R. Tascher	Reid Yellow Dent, Boone County White, Johnson County White, Commercial White, miscellaneous other varieties.
Montana: Northern Montana Branch Station, Havre.	1928	M. A. Bell		Northwestern Dent, Pioneer White Dent, Falconer Semi-dent, Minnesota 13, Gehu Yellow Flint, Dakota White Flint, Burleigh County Mixed Flint, Rainbow Flint.
Nebraska: Agricultural Experiment Station, Lincoln.	1909	T. A. Kiesselbach	E. G. Montgomery	Hogue Yellow Dent, Nebraska White Prize, Reid Yellow Dent, Krug, Cattle Corn, St. Charles White.
Branch Experiment Station, North Platte.	1925	L. L. Zook	G. F. Sprague, N. E. Jodon	North Platte White, North Platte Yellow, McCulloch White, McCulloch Yellow, Flour Corn, Australian White Flint, Calico, Bloody: Butcher.
New Jersey: Agricultural Experiment Station, New Brunswick.	1921	H. B. Sprague, G. W. Burton, M. E. Paddick, R. E. Blaser.	E. E. Evaul	More than 300 varieties are carried in the nursery, representing acquisitions from all parts of the world.
New York: Agricultural Experiment Station, Ithaca.	1919	R. G. Wiggans	C. B. Hutchison	Cornell 11, Onondaga White Dent, Alvord White Cap Dent, Luces Favorite, Webber Dent, Cornell 12, West Branch Sweepstakes, Leaming, Dutton Flint, Argentine Yellow Flint, Spanish Yellow Flint, Latting Red Cob White, United States Select 193, United States Selection 204, Silver King, Rustler White Dent, Early Sanford White Flint, Bloody Butcher. About 34 miscellaneous additional varieties are being carried in the inbreeding nursery.
North Carolina: Agricultural Experiment Station, State College Station, Raleigh.	1931	G. K. Middleton		Yellow Horsetooth.
North Dakota: Agricultural Experiment Station, Fargo.	1923	P. J. Olson, William Wiidakas	L. R. Waldron	Dakota White Flint, Gehu Yellow Flint, Minnesota 13, Northwestern Dent, Ivory King, Mandan King, Falconer Semi-dent.
North Dakota: Bureau of Plant Industry, Division of Dry Land Agriculture: Northern Great Plains Field Station, Mandan.[1]	1924	J. C. Thysell		Northwestern Dent.

See footnotes at end of table.

TABLE 2.—*Location of projects on corn improvement based on selection in inbred lines*—Continued

State, institution, and location	Date begun	Present personnel	Former investigators	Varieties included
North Dakota—Continued.				
Bureau of Plant Industry, Division of Cereal Crops and Diseases:				
Dickinson Substation, Dickinson	1923	R. W. Smith		Northwestern Dent, Falconer Semi-dent, Minnesota 13.
Ohio:				
Agricultural Experiment Station, Wooster and Columbus.[1]	1919	G. H. Stringfield	M. T. Meyers, Louis Jorgenson	Clarage (Eichenberger and Wooster strains), Medina Pride, Lancaster Surecrop, strains from ear-to-row breeding, selected strains for high-ear, low-ear, high-percent grain, and low-percent grain, and unnamed local varieties.
Oklahoma:				
Agricultural Experiment Station, Stillwater.	1931	C. B. Cross		Chisholm, Colby Bloody Butcher, Early Rose, Estill Yellow Dent, Ferguson Yellow Dent, Freed White Dent, Funk 176 A, Golden Republic, Hastings Prolific, Hays Golden, Mexican June, Midland Yellow Dent, Minnesota 13, Neal Paymaster, Oklahoma Silvermine, Pride of Saline, Reece Drought Resister, Reid Yellow Dent, Surcropper, Waugh Early Yellow Dent, Whatley Prolific, Williams Yellow Dent, and several additional strains of more local distribution.
South Dakota:				
Agricultural Experiment Station, Brookings.	1927	A. N. Hume, Mathew Fowlds, Clifford Franzke.		Dakota No. 86, Wimple Yellow Dent, Murdock.
Tennessee:				
Agricultural Experiment Station, Knoxville.[1]	1922	L. S. Mayer		Delta Prolific, Jarvis Golden Prolific, Neal Paymaster.
Texas:				
Agricultural Experiment Station, College Station.	1927	P. C. Mangelsdorf		Surcropper, Blue Grain.
Substation no. 1, Beeville	1927	R. A. Hall		Surcropper, Thomas.
Substation no. 3, Angleton	1927	R. H. Stansel		Surcropper, Tuxpan.
Substation no. 5, Temple	1928	Henry Dunlavy		Mosshart Yellow Dent.
Substation no. 6, Denton	1927	P. B. Dunkle		Surcropper, Denco Yellow Dent.
Substation no. 11, Nacogdoches	1927	H. F. Morris		Surcropper, Nacogdoches.

Virginia:				
Agricultural Experiment Station, Blacksburg.	1925	T. B. Hutcheson, N. A. Pettinger	T. K. Wolf	Reid Yellow Dent, Silver King.
Bureau of Plant Industry, Division of Cereal Crops and Diseases:				
Arlington Experiment Farm, Rosslyn.	1916	M. T. Jenkins, F. D. Richey	C. P. Hartley, C. H. Kyle, Hugo Stoneberg, H. S. Garrison.	Whatley Prolific, Garrick Prolific, Cuban Yellow Flint, Silver King, Boone County White, Delta Prolific, and a large number of other domestic varieties and foreign introductions.
Washington:				
Agricultural Experiment Station, Pullman.	1931	E. F. Gaines		Thayer Yellow Dent, Windus White Dent.
West Virginia:				
Agricultural Experiment Station, Morgantown.	1920	R. J. Garber, C. R. Burnham	M. M. Hoover	Blue Ridge, Golden Glow, Lancaster Surecrop, Pickens White, Reid Yellow Dent, Boone County White, Leaming, Cocke Prolific, Woodburn White Dent, Eldridge, Johnson County White, and several local varieties.
Wisconsin:				
Agricultural Experiment Station, Madison and Spooner.[1]	1923	N. P. Neal, A. H. Wright, R. A. Brink, B. D. Leith, J. G. Dickson, O. S. Aamodt, A. M. Strommen,[3] E. J. Delwiche,[3] Paul Hoppe.		Golden Glow, Silver King, Wisconsin No. 8, Murdock, Reid Yellow Dent, Golden Chippewa, Wisconsin No. 25.

[1] In cooperation with the Bureau of Plant Industry, Division of Cereal Crops and Diseases, U. S. Department of Agriculture.
[2] In cooperation with the Illinois Agricultural Experiment Station, Urbana, Ill., and Funk Bros. Seed Co., Bloomington, Ill.
[3] Located at branch experiment station, Spooner.

Table 3.—*Summary of the performance of the outstanding inbred lines developed as a result of the inbreeding programs. The performance of each line in hybrids is expressed as a percentage of the average performance of all hybrids or of the check varieties with which it was compared*

State, institution, and location	Line	Parent variety	Generations selfed	Performance in hybrids: Years tested	Acre yield	Resistance to lodging	Resistance to moldy ears	Resistance to smut	Other characteristics
			Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	
Arizona:									
Bureau of Plant Industry, Division of Genetics and Biophysics, Sacaton.	18 Bo 48	Sacaton June	10	1	125				
	19 Bo 106	do	9	1	125				
California:									
Agricultural Experiment Station, Berkeley.	53 (227) 33	King Philip Hybrid	7	1	108	120		(1)	Smut susceptible.
	133 (227) 33	do	7	1	124	120		(1)	Freckled leaves.
	118 (227) 33	do	7	1	99	100		(1)	Tassel seed in suckers.
	164 (227) 33	do	7	1	107	120		(1)	No suckers.
	160 (227) 33	do	7	1	128	100		(1)	Late.
	65 (227) 33	do	7	1	129	90		(1)	Late, low ears, no suckers.
	100 (227) 33	do	7	1	114	80		(1)	Weak stalks, reddish.
	93 (227) 33)	do	7	1	104	100		(1)	Late.
	96 (227) 33	do	7	1	110	80		(1)	Do.
Colorado:									
Agricultural Experiment Station, Fort Collins.	Lines 10 days earlier than average:								
	9045	Minnesota 13	13	1	111				
	9049	do	13	1	126				
	9054	do	13	1	127				
	9059	do	11	1	108				
	9064	do	12	1	131				
	9070	do	13	1	127				
	9074	do	13	1	109				
	9088	do	12	2	117				
	Lines of average maturity:								
	9092	Minnesota 13	13	2	110				
	9094	do	13	1	127				
	9096	do	15	2	121				
	9099	do	15	1	111				
	9123	Pioneer White Dent	11	2	116				

nnecticut:									
Agricultural Experiment Station, New Haven.	Lines 10 days earlier than average:								
	14–4	Stadtmueller Leaming	4+	10+	120	80	80	100	
	112–1	Beardsley Leaming	4+	10+	110	100	80	50	
	112–6	do	4+	10+	110	100	100	50	
	112–9	do	4+	10+	110	80	80	75	
	112–12	do	4+	10+	110	80	80	75	
	Lines of average maturity:								
	243	Chester Leaming	30	30	120	100	100	100	
	20	Burr White	10+	10+	120	120	100	100	Very leafy, good root system.
	21	do	10+	10+	120	80	80	50	Very leafy.
rida:									
Agricultural Experiment Station, Gainesville.	B1–18	Selfed line of Cuban Yellow Flint × Synthetic Variety B.[2]	7	2	130	153	116	[3] 114	Heavy stalk.
	B11–25	Selfed line from U. S. Department of Agriculture double cross of Boone County White, Garrick Prolific, and Cuban Yellow Flint × Synthetic Variety B.[2]	7	2	104	138	120	[3] 76	Dark green, tissues tough.
	B12–8	Georgia College selfed Whatley × Synthetic Variety B.[2]	7	2	109	109	117	[3] 113	Yellow, prolific, short heavy stalk.
	3–237	Tisdale	8	2	115	121	117	[3] 113	Long, heavy husk.
	5–27	Wilson	8	2	108	125	113	[3] 116	Dark green, short heavy stalk, long husk.
	97–1	Hastings Prolific	9	2	135	103	118	[3] 71	Very prolific.
	16–8	Florida Flint × Cuban White Flint.	9	2	112	104	113	[3] 103	Dark green, long husk.
	29–11	U. S. Department of Agriculture double cross of Boone County White, Garrick Prolific, and Cuban Yellow Flint.	9	2	128	115	114	[3] 83	Very good on Everglades muck, flinty.
	155–1	C. I. 579C-7-1	6	2	122	152	111	[3] 107	Flinty.
orgia:									
Agricultural Experiment Station, Experiment.	Lines of average maturity:								
	22	Garrick × Creole	10	1		100	90	100	Vigorous.
	23	do	9	1		100	90	100	Do.
	500	Steinheimer	8	1		110	100	100	Vigorous, easy to self-pollinate and continue for breeding material.
Coastal Plain Experiment Station, Tifton.[4]	Long season corn:								
	B	F_1 Cross	5	1	100+	130	120		Excellent husk protection and drought resistant.
nois:									
Agricultural Experiment Station, Urbana.[4]	Lines 10 days earlier than average:								
	4451	Illinois Low-Ear	10	2	110	130	110	110	Early, low ear, good grain quality.

See footnotes at end of table.

TABLE 3.—*Summary of the performance of the outstanding inbred lines developed as a result of the inbreeding programs. The performance of each line in hybrids is expressed as a percentage of the average performance of all hybrids or of the check varieties with which it was compared*—Continued

State, institution, and location	Line	Parent variety	Generations selfed	Performance in hybrids: Years tested	Acre yield	Resistance to lodging	Resistance to moldy ears	Resistance to smut	Other characteristics
Illinois—Continued.									
Agricultural Experiment Station, Urbana.[4]	Lines of average maturity:		*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	
	4211	Cross between lines from Funk 176A and Illinois Low-Ear.	8	3	115	110	100	120	Reduces ear height, increases yield.
	5120	Illinois High-Yield	9	4	110	130	130	120	Ears well covered, held erect, grain high quality, foliage tends to remain green.
Bureau of Plant Industry, Division of Cereal Crops and Diseases, Bloomington.[5]	Lines 1 week earlier than average:								
	A	Funk Yellow Dent	18	14	115	110	115	120	Does not tiller; good husk and quality of grain; increases resistance of stalk and shank tissues to chilling temperatures in early fall; susceptible to chinch bugs and lacks strength of stalk in late fall.
	90	Funk 90-Day	12	7	110	105	125	100	Very resistant to ear rots; good husk; lacks in stalk rot resistance.
	K	Hays Golden	13	5	110	105	110	105	Adds deeper yellow color; increases oil and protein content; adds cold resistance in fall; resistant to chinch bugs; lacks husk protection.
	M14	Single Cross 10 × R8	10	4	115	110	90	110	Adds length of ear; has strong tendency for lowering height of ear on stalk.
	Lines of average maturity:								
	R4	Funk Yellow Dent	18	14	120	100	120	110	Lacks in cold resistance in early fall, also lacks in strength of stalk in late fall; resistant to ear rots, good husk, 2-ear inbred; goes through heat and drought periods well; resistant to corn borer; dries quickly following maturity.

	Hy	Illinois High-Yield	12	7	110	125	110	110	Exceptionally well anchored; adds strength of stalk in late fall; resistant to chinch bugs and root worm; increases shelling percentage of grain.
	L	Mann Leaming	15	10	120	100	100	90	Adds length of ear and size of seed and rich yellow color to grain; ears are lower than average on stalk.
	D4	Single Cross A × Hy	4	1	120	125	120	120	Resistant to root worms and chinch bugs.
Indiana: Agricultural Experiment Station, Lafayette.[4]	Lines 10 days earlier than average:								
	54–14	Early Yellow Dent	10	3	113	94	105	100	Short plant, low ears.
	66–24	do	10	3	106	102	104	105	Dilute purple seedlings in cold soil.
	C6	Reid Yellow Dent	10	3	106	94	100	94	Short thick ear.
	H6	do	8	3	106	95	93	106	Long slender tapering ear.
	Lines of average maturity:								
	WF9	do	8	3	120	100	110	98	Low ear, medium long shank.
	Tr	do	10	3	111	103	95	85	Short plant, low thick ear, poor husk covering.
	B2	do	10	3	114	104	84	100	Stiff stalk, low ear, thin pericarp.
	T92	do	6	3	106	105	105	110	High ear, very stiff stalk.
	Lines 10 days later than average:								
	38–11	do	6	3	114	104	106	90	Cold resistant, excellent root system.
	2–14	Johnson County White	10	3	114	99	111	105	Weak plant, good quality grain.
	33–16	do	10	3	115	103	84	105	Good root system—may top burn.
Iowa: Agricultural Experiment Station, Ames:[4] Farm Crops Section.	Lines 10 days earlier than average:								
	4Co 13	Four County White	8	5	110	80	103	100	Relative tillering [6] 100.
	4Co 31	do	8	5	115	100	105	101	Do.
	4Co 82	do	8	5	115	120	106	100	Relative tillering [6] 120.
	4Co 101	do	8	5	114	100	107	101	Relative tillering [6] 100.
	SK 111	Silver King	8	5	107	90	103	101	Relative tillering [6] 120.
	US 153	United States Selection 133	8	5	103	100	100	100	Relative tillering [6] 100.
	Cl 447	Clark Yellow Dent	8	5	100	125	102	98	Relative tillering [6] 120.
	Lines of average maturity:								
	I 197	Iodent	8	5	101	120	100	97	Do.[6]
	I 205	do	8	5	110	140	90	102	Relative tillering [6] 100.
	I 224	do	8	5	115	125	110	105	Relative tillering [6] 120.
	I 234	do	8	5	110	115	98	100	Do.
	L 289	Lancaster Surecrop	8	5	112	110	99	100	Relative tillering [6] 100.
	Bl 349	Black Yellow Dent	8	5	110	100	105	100	Relative tillering [6] 160.
	KB 397	Krizer Bros. Yellow Dent	8	5	112	120	100	98	Relative tillering [6] 100.
	Os 420	Osterland Yellow Dent	8	5	110	120	105	102	Do.
	Os 426	do	8	5	110	100	102	100	Relative tillering [6] 160.
	WD 456	Walden Dent	8	5	110	105	95	100	Relative tillering [6] 100.

See footnotes at end of table.

TABLE 3.—*Summary of the performance of the outstanding inbred lines developed as a result of the inbreeding programs. The performance of each line in hybrids is expressed as a percentage of the average performance of all hybrids or of the check varieties with which it was compared*—Continued

State, institution, and location	Line	Parent variety	Generations selfed	Performance in hybrids: Years tested	Acre yield	Resistance to lodging	Resistance to moldy ears	Resistance to smut	Other characteristics
Iowa—Continued.									
Agricultural Experiment Station, Ames:[4]	Lines 10 days later than average:		*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	
Farm Crops Section.	I 159	Iodent	8	5	120	135	110	98	Relative tillering [6] 140.
	L 317	Lancaster Surecrop	8	5	118	100	98	101	Relative tillering [6] 100.
	Bl 345	Black Yellow Dent	8	5	110	90	98	101	Relative tillering [6] 160.
	Bl 351	do	8	5	112	100	98	100	Relative tillering [6] 100.
	Mc 401	McCulloch Yellow Dent	8	5	110	110	95	101	Relative tillering [6] 200.
	ITE 701	Illinois Two-Ear	8	5	120	120	110	100	Relative tillering [6] 100.
	Lines 10 days earlier than average:								
Genetics Section	CL	Clark Yellow Dent	8-10	3	105	90	110	110	Seed quality 140.
	Mc	McCulloch Yellow Dent	8-10	3	110	120		100	Do.
	SE	United States Selection 133	8-10	3	110	90	110	110	Do.
	WC	Wisconsin Cold Resistant	6	2	110	110		110	Seed quality 120.
	Lines of average maturity:								
	La	Lancaster Surecrop	9	5	112	100		100	Ear type 120; plant type 100.
	Ldg	do	9	6	120	105		105	Ear type 120; plant type 140.
	Jdt	Iodent	9	6	115	140	100	110	Ear type 130; plant type 120.
	Osf	Osterland Yellow Dent	9	5	108	110		110	Ear type 120; plant type 110.
	Bls	Black Yellow Dent	9	6	115	90		100	Ear type 110; plant type 110.
	ex La 4134	"Second Cycle"	[7] 6	2	120	110		110	Ear type 120; plant type 120.
	ex Ldg 4182	do	[7] 6	2	125	105		100	Ear type 110; plant type 120.
	ex Ldg 4186	do	[7] 6	2	125	105		100	Do.
	Lines 10 days later than average:								
	Pr	Proudfit Yellow Dent	9	5	115	110	100	110	Plant type 120.
	ex Ldg 4224	"Second Cycle"	[7] 6	1	115	130		110	Do.
Kansas:									
Agricultural Experiment Station, Manhattan.[4]	Lines 10 days earlier than average:								
	CB1	Blue Squaw	7	4	120	75	80	70	Resistance to heat and drought 140; purple aleurone.
	CB5	Dawson County Yellow Dent	7	4	110	90	85	90	Resistance to heat and drought 125; very early.

	CB8	Colby Bloody Butcher	8	4	120	120	110	120	Resistance to heat and drought 120; red pericarp.
	CB14	do	7	4	110	120	120	120	Resistance to heat and drought 115; red pericarp.
	CB28	Hays Golden	7	4	125	120	115	120	Resistance to heat and drought 120.
	CB25	Illinois High-Yield	10	4	120	110	110	110	Resistance to heat and drought 115.
	CB28	do	10	4	115	115	110	110	Resistance to heat and drought 105.
	CB42	Illinois Low-Ear	4	1	95	125	115	105	Resistance to heat and drought 110.
	CB41	Pride of Saline	6	3	110	115	115	120	Resistance to heat and drought 120.
	Lines of average maturity:								
	CB48	Yellow Selection No. 1	4	2	125	120	115	115	White cob.
	CB50	do	6	2	115	110	105	115	Do.
	CB51	do	6	2	120	110	115	110	Do.
	CB53	do	6	2	115	115	115	100	Do.
	CB60	do	6	2	115	115	110	110	Do.
	CB63	do	5	2	115	115	110	110	Do.
	CB66	do	6	2	120	120	110	100	White cob, dark green.
	CB5	Pride of Saline	6	2	115	110	110	105	
	CB10	do	6	2	115	120	115	120	
	CB14	do	6	2	120	120	115	115	
	CB39	do	6	2	115	115	115	105	
	CB26	Illinois High-Yield	10	4	125	120	115	120	
	CB27	do	10	6	125	120	120	120	
	Lines 10 days later than average:								
	CB55	Yellow Selection No. 1	6	1	110	115	115	105	White cob.
	CB75	do	6	1	115	100	110	110	Do.
	CB34	Pride of Saline	6	2	115	110	105	110	
	CB60	do	6	2	120	115	105	115	
	10646	Kansas Sunflower	7	4	120	105	110	110	
	10647	do	6	4	120	120	115	110	
	10649	do	5	4	120	115	110	110	
	10651	do	5	4	120	120	110	110	
Kentucky: Agricultural Experiment Station, Lexington.	50	Boone County White	14	6	100	105	115	115	Medium early, sound stalks, corn hard and sound.
	41	do	12	4	110	120	100	90	Short, thick stalk; poor tip covering.
	39	do	11	6	115	90	120	120	Tall, slender stalk; lodges, good tip covering, long shank, very hard, sound.
	27	Local White	12	5	105	115	120	120	Stalk dies early, good tip covering.
	30	Boone County White	11	5	110	110	100	100	
	21	do	11	5	110	100	100	100	Ear slender.
	89	Neal Paymaster	6	2	100	120	115	115	Late, stiff, vigorous, short shank.
	55	Reid Yellow Dent	14	5	85	115	120	120	Early strain, slender ear.
	53	do	12	5	95	115	90	75	Early strain; these early yellow strains do not yield as heavily in combinations as later white strains.

See footnotes at end of table.

Table 3.—*Summary of the performance of the outstanding inbred lines developed as a result of the inbreeding programs. The performance of each line in hybrids is expressed as a percentage of the average performance of all hybrids or of the check varieties with which it was compared*—Continued

State, institution, and location	Line	Parent variety	Generations selfed	Performance in hybrids: Years tested	Acre yield	Resistance to lodging	Resistance to moldy ears	Resistance to smut	Other characteristics
Louisiana:									
Agricultural Experiment Station, Baton Rouge.[4]	Lines of average maturity:		*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	
	C 28-2	Cocke Prolific	6	4	113	100+		[3] 110	
	C 28-10	do	6	4	114	100+		[3] 110	
	C 28-30-2	do	6	4	112	100+		[3] 110	
	C 28-55	do	6	3	119	100+		[3] 110	
	C 28-61	do	6	3	112	100+		[3] 110	
	C 27-141	do	7	4	126	100+		[3] 110	
	C 27-151	do	7	4	113	100+		[3] 110	
	C 26-102-1	do	8	4	110	100+		[3] 110	
	D 27-178	Delta Prolific	7	4	119	100+		[3] 110	
	H 27-204	Hastings Prolific	7	3	112	100+		[3] 110	
	W 27-207-2	Whatley Prolific	7	4	113	100+		[3] 110	
	Cr. 28-48	Creole Yellow Flint	6	3	110	100+		[3] 120	
	Cr. 28-107	do	6	4	111	100+		[3] 120	
	Cr. 28-162	do	6	4	113	100+		[3] 120	
Michigan:									
Agricultural Experiment Station, East Lansing.	Lines 10 days earlier than average:								
	D2486	Duncan	6	1	126	100	100	100	Early, leafy, vigorous.
	P2485	Polar Dent	7	1	126	100	100	100	Cold resistant, leafy strain.
	D2011	Duncan	6	1	124	100	100	100	Good root system, stiff stalked.
	32286	N W D × M. Amargo	6	1	108	100	100	100	Corn-borer resistant.
	32275	Duncan × M. Amargo	6	1	114	100	100	100	Corn-borer resistant, vigorous.
	Lines of average maturity:								
	D2539	Duncan	7	1	173	100	100	100	Vigorous, good color, good roots.
	D2541	do	7	1	173	100	100	100	Good tassel, good pollinator.
	20585	Duncan × M. Amargo	7	1	146	100	100	100	Corn-borer resistant, uniform height.
	20562	Golden Glow × M. Amargo	7	1	151	100	100	100	Medium green, small ear, good tassel.
	Lines 10 days later than average:								
	P2079	Polar Dent	5	1	135	100	100	100	Frost resistant, leafy, vigorous.
	D2077	Duncan	5	1	135	100	100	100	Vigorous, good root system.
	30006	Red Cob Ensilage × M. Amargo	8	1	180	100	100	100	Corn-borer resistant, large ears and stalks.
	20534	Golden Glow × M. Amargo	7	1	116	100	100	100	Corn-borer resistant, uniform, vigorous.

Minnesota:									
Agricultural Experiment Station, University Farm, St. Paul.	Group 1 (lines used in crosses distributed to growers):								
	Lines of average maturity:								
	11	Minnesota 13	9	10	115	75		90	Large kernel, ear smut.
	14	do	15	10	115	110		100	Tillers, 2-ear, small kernel.
	15	Rustler White Dent	10	10	115	70		125	Good ear, creamy white.
	16	do	10	10	115	110		85	Good ear, small kernel.
	19	do	11	10	115	125		75	Slightly loose pericarp.
	20	do	11	10	115	110		125	Very good luster.
	Line 20 days later than average:								
	B164 [8]	Reid Yellow Dent	4	3	120	125		75	Very good vigor, good pollen.
	Group 2 (lines selected for top cross study):								
	a. Lines from varieties:								
	25 lines	Minnesota, 13	7-13			125-75		125-75	
	10 lines	Rustler White Dent	4-15			125-75		125-75	
	12 lines	Northwestern Dent	8-15			125-75		125-75	
	6 lines	Minnesota, 23	4-5			125-75		125-75	
	9 lines	Others	7-16			125		125-75	
	b. Lines from crosses:								
	109 lines		6-8			125		125-100	
	c. Parental nonlodging lines (used to obtain new nonlodging recombinations at University Farm and at Waseca):								
	64	Northwestern Dent	9			125		75	
	49	Minnesota, 13	9			125		125	
	15-28	Rustler White Dent	4			125		100	
	8-29	Purdue Yellow Dent				125		125	
	9-29	Osterland Yellow Dent				125		125	
	H	Reid Yellow Dent	14			125		100	
	4-29	Silver King	8			125		75	
	46	Minnesota, 13	8			125		125	
Southeast Experiment Station, Waseca.	Group 1 (lines used in crosses distributed to growers):								
	374 [9]	Reid Yellow Dent	12	3	120	125		100	Very good vigor.
	375 [9]	do	10	3	120	125		100	

See footnotes at end of table.

TABLE 3.—*Summary of the performance of the outstanding inbred lines developed as a result of the inbreeding programs. The performance of each line in hybrids is expressed as a percentage of the average performance of all hybrids or of the check varieties with which it was compared*—Continued

State, institution, and location	Line	Parent variety	Generations selfed	Performance in hybrids: Years tested	Acre yield	Resistance to lodging	Resistance to moldy ears	Resistance to smut	Other characteristics
Minnesota—Continued. Southeast Experiment Station, Waseca.	Group 2 (lines selected for top cross study):								
	a. Lines from varieties:		*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	
	18 lines	Silver King	7-10			125-75		75-50	
	13 lines	Golden King	5			125-75		75-50	
	16 lines	Others	8-16			125-75		75-50	
	b. Lines from crosses:								
	80 lines		6			125		115-75	
Mississippi: Agriculture Experiment Station, State College.	JS391	Jarvis Golden Prolific	5	1	125	100	110		Medium early, semihard kernels.
	S3118	Ferguson Yellow Dent	8	1	125	100	100		Well anchored, fairly soft kernels.
	S3124	do	8	1	118	100	105		
	S3196	Laguna	10	1	117	110	100		Very uniform, excellent husk covering.
	4S3167	Cocke Prolific	6	1	115	115	120		
Missouri: Agriculture Experiment station, Columbia.[4]	Lines of average maturity:								
	B50	Boone County White	12	3	115	100		120	Closely related lines, produce good quality grain.
	B51	do	12	3	108	120		120	Do.
	B62	do	12	3	111	100			Retains green color late in fall, good quality.
	J33	Johnson County White	12	5	103	110		120	2-eared.
	L3	Lancaster Surecrop	11	5	109	100		120	Dark green color, scanty pollen production.
	R104	Reid Yellow Dent	13	5	108	120		110	Susceptible to ear rots.
	Lines 10 days later than average:								
	B54	Boone County White	12	3	111	120		120	Ear has high number of kernel rows susceptible to rots, resistant to heat and drought.
	G	Mastodon	11	5	102	110		100	Large, heavy stalk, exposed ear tips, scanty pollen production.
	K1	Kansas Sunflower	11	5	112	111		120	Fasciated ear tip.
	K4	do	11	5	114	110		100	2-eared, resistant to heat and drought.

Montana: Northern Montana Branch Station, Havre.	Gehu (A)	Gehu Yellow Flint	6	1	(10)	(11)	(11)	(11)	Tillers freely, early.
	Gehu (B)	do	6	2					Later than Gehu A.
	DWF (A)	Dakota White Flint	6	2					Leafy, good tassels.
	Pioneer (A)	Pioneer White Dent	6	2					Upright, no tillers.
	Rainbow (A)	Rainbow Flint	6	2					Light green.
	Burleigh (A)	Burleigh County Mixed	5	1					Very early.
	Falconer (A)	Falconer Semi-dent	6	2					Very short.
Nebraska: Agricultural Experiment Station, Lincoln.	Lines 10 days earlier than average:								
	Illinois, A-R-7	Funk 176A		7	105	100		120	Tasseling date of line July 24.
	Indiana, 54-14	Early Yellow Dent		5	97	103		100	Do.
	Ohio 2614	Nebraska 751 X Nebraska 2 (Hogue Yellow Dent Lines).		6	90	106		112	Tasseling date of line July 25.
	Nebraska G. R. 95	Reid Yellow Dent	7			111		140	Do.
	Lines of average maturity:								
	Iowa Os 420	Osterland Yellow Dent		7	110	60		87	Tasseling date of line July 26.
	Iowa Os 426	do		7	108	60		76	Do.
	Illinois L	Leaming		7	98	78		100	Tasseling date of line July 27.
	Indiana 66-24	Early Yellow Dent		7	106	93		85	Do.
	Nebraska Krug-43	Krug	4			130			Do.
	Nebraska 111-61	Hybrid	4			125			Do.
	Illinois B-R-10	Funk Yellow Dent		7	90	130		100	Do.
	Iowa I 234	Iodent		5	110	120		130	Tasseling date of line July 28.
	Iowa L 289	Lancaster Surecrop		6	110	115		130	Do.
	Iowa I 197	Iodent		7	103	60		100	Do.
	Illinois 90	Funk 90-Day		4	96	120		118	Do.
	Nebraska G. R. 99	Reid Yellow Dent	7			112		82	Do.
	Ohio 608-B	Nebraska 725 X Nebraska 2 (Hogue Yellow Dent lines).		4	90	105		66	Do.
	Kansas H. G. 6633	Hays Golden		5	100	112		140	Tasseling date of line July 29.
	Illinois Hy	Illinois High Yield		4	100	112		127	Do.
	Indiana B-2	Reid Yellow Dent		7	105	122		120	Do.
	Indiana 46-12	Early Yellow Dent		7	108	90		117	Tasseling date of line July 30.
	Kansas 7492	Freed White Dent		6	95	120		82	Do.
	Illinois A-R-4	Funk 176A		5	100	60		125	Do.
	Kansas 6626	Hays Golden		7	100	108		118	Tasseling date of line July 31.
	Iowa I 205	Iodent		7	95	118		133	Do.
	Indiana 461-3-1-3	Reid Yellow Dent		4	105	123		91	Do.
	Lines 10 days later than average:								
	Nebraska 469-58	Hybrid	4			90			Tasseling date of line August 2.
	Nebraska G. R. 100	Reid Yellow Dent	7			85		98	Do.
	Kansas 7505	Freed White Dent		6	96	108		100	Tasseling date of line August 3.
	Iowa Pr 363	Proudfit Yellow Dent		5	95	65		60	Do.
	Iowa L 317	Lancaster Surecrop		4	100	115		102	Tasseling date of line August 4.
	Iowa I 159	Iodent		5	95	70		71	Tasseling date of line August 7.

See footnotes at end of table.

TABLE 3.—*Summary of the performance of the outstanding inbred lines developed as a result of the inbreeding programs. The performance of each line in hybrids is expressed as a percentage of the average performance of all hybrids or of the check varieties with which it was compared*—Continued

State, institution, and location	Line	Parent variety	Generations selfed	Performance in hybrids: Years tested	Acre yield	Resistance to lodging	Resistance to moldy ears	Resistance to smut	Other characteristics
			Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	
Nebraska—Continued.									
Branch Experiment Station, North Platte.	Lines 10 days earlier than average:								
	S. S. Y. 11-1-3	North Platte Yellow	7					95	Tasseling date of line July 20.
	S. S. W. 27-7	North Platte White	7					125	Tasseling date of line July 22.
	S. S. Y. 4-1-2	North Platte Yellow	7					94	Tasseling date of line July 25.
	AF 6-1-1	Australian Flint	7	5	111				
	BB 4-2-1	Bloody Butcher	7	5	101				
New Jersey:									
Agricultural Experiment Station, New Brunswick.	Lines of average maturity:								
	A12	Cooley Yellow Dent	10	6	120	140	125	120	Green color, 140.
	A21	Brewer Yellow Dent	10	6	105	100	125	120	Green color, 100.
	A30	Mondell Yellow Dent	10	6	120	150	125	120	Green color, 110.
	A37	Great Valley Yellow Dent	10	6	115	100	100	120	Do.
	A47	Reid White Cap	10	6	130	140	125	120	Green color, 130.
	A49	Schmidt White Cap	10	6	110	100	125	120	Green color, 110.
	A58	Hageman White Dent	10	6	115	75	100	120	Do.
	A60	Schmidt White Cap	10	6	115	100	125	120	Do.
	A64	Brewer Yellow Dent	10	6	110	140	125	120	Green color, 115.
	B5	Leaming	15+	6	120	150	125	120	Green color, 110.
	B7	Burr White	15+	6	115	150	125	120	Do.
	B8	Burr White	15+	6	115	140	125	120	Do.
	B19	Nebraska White Prize	15+	6	115	140	100	120	Green color, 130.
New York:									
Agricultural Experiment Station, Ithaca.	35-1	Lucas Favorite	15		(12)	125		100	Medium late.
	35-2	Onondaga White Dent	15		(12)	100		100	Early.
	35-3	Cornell 11	15		(12)	100		100	Do.
	35-4	Bloody Butcher	14		(12)	75		75	Medium early.
North Carolina:									
Agricultural Experiment Station, Raleigh.	4D1	Yellow Horsetooth	5	1	121	120			Stocky, tendency to tiller.
	57A2	do	5	1	121	120			Do.
	16A2	do	5	1	129	100			Gives medium tall hybrids.
	8A3	do	5	1	129	100			Do.

North Dakota: Agricultural Experiment Station, Fargo.	Lines of average maturity:								
	91	Minnesota 13	5	3	100+	100+			
	106	do	5	3	100+	100+			
	178	do	5	3	100+	100+			
	207	do	5	3	100+	100+			
	210	do	5	3	100+	100+			
	211	do	5	3	100+	100+			
	212	do	5	3	100+	100+			
	267	do	5	3	100+	100+			
	318	Northwestern Dent	5	2	100+	100+			
	331	do	5	2	100+	100+			
	354	do	5	2	100+	100+			
	386	do	5	2	100+	100+			
	390	do	5	2	100+	100+			
	434	do	5	2	100+	100+			
	437	do	5	2	100+	100+			
	B28	Dakota White Flint	4	5	100+	100+			
	A10	do	4	5	100+	100+			
	A17	do	4	5	100+	100+			
	A28	do	4	5	100+	100+			
Ohio: Agricultural Experiment Station, Wooster and Columbus [4]	Lines 10 days earlier than average:								
	26	Wooster Clarage	10	5	110	100	100	105	Dies early, tillers.
	332A	do	9	5	110	90	100	100	Stalks break early.
	51	do	10	5	115	90	110	120	Tillers, good-quality grain.
	517E	Ohio Ear-to-Row Strain	10	6	115	120	70	70	Low ear, 2-ear, poor husk, exceptionally well anchored, breeding material.
	65	do	10	6	105	120	100	90	Low ear, tillers, fasciated cob.
	84	do	10	6	115	110	105	110	Leafy, probably our best all-around early line.
	93C	Ohio Low Ear × Illinois Low Ear	5	2	110	110	100	100	Earliest Ohio lines, low ear.
	Lines of average maturity:								
	21	Wooster Clarage	10	4	110	90	100	90	Color, 120; tillers, 120; husk cover, 75.
	56	do	10	4	115	120	110	105	Short husk, top leaves unroll too slowly.
	616B	Burr Leaming Double Cross	9	4	110	110	105	90	White cap, good quality grain, dominant long husk, multiple ear.
	614B	do	9	3	100	100	90	90	Ripe grain on green plants.
	32	Eichelberger Clarage	10	6	110	90	100	100	Tall, slender, resistant to corn borer.

See footnotes at end of table.

TABLE 3.—*Summary of the performance of the outstanding inbred lines developed as a result of the inbreeding programs. The performance o[f] each line in hybrids is expressed as a percentage of the average performance of all hybrids or of the check varieties with which it was com[-]pared*—Continued

State, institution, and location	Line	Parent variety	Generations selfed	Performance in hybrids: Years tested	Acre yield	Resistance to lodging	Resistance to moldy ears	Resistance to smut	Other characteristics
Ohio—Continued. Agricultural Experiment Station, Wooster and Columbus.	Lines 10 days later than average:		*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	
	20	Eichelberger Clarage	15	9	100	80	100	105	Corn borer resistant.
	61	Burr Leaming Double Cross	9	4	110	100	110	90	Long ear, long husk, good-quali[ty] grain.
	47	Eichelberger Clarage	10	4	110	90	100	100	Vigorous seedling, large, tall.
	67	do	10	4	110	115	100	100	Heavy pollen producer, long shan[k], tendency for multiple ears.
	73B	do	10	4	110	100	80	80	Large, thick culm, vigorous, leaf[y].
	10	do	10	4	115	95	105	100	Excellent line with stiff mat[...] medium long ear.
South Dakota: Agricultural Experiment Station, Brookings.	1210-1	Alta	9	4	128	100	100	90	
	1210-4	Brookings 86	9	4	122	100	100	95	
	1210-7	Reid Yellow Dent	8	3	117	100	100	95	
	1210-13	Wimple Yellow Dent	7	2	142	100	100	90	
	1210-15	Northwestern Dent	8	2	127	100	100	95	
Tennessee: Agricultural Experiment Station, Knoxville.[4]	Lines of average maturity:								
	10	Neal Paymaster	5	2	110-120				
	14	do	5	2	110-120				
	43	do	5	2	110-120				
	47-1	do	5	2	110-120				
	74-2	do	5	2	110-120				
	75-2	do	5	1	110-115				
	76	do	5	2	110-120				
	93	do	5	2	110-120				
	2	do	5	1	120-130				
	4	do	5	2	120-130	(13)	(13)	(13)	
	15	do	5	2	120-130				
	47-2	do	5	2	120-130				
	75-1	do	5	1	120-130				
	85-2	do	5	2	120-130				
	102	do	5	2	120-130				
	J5-5	Jarvis Golden Prolific	8	1	115-120				
	J7-2	do	8	1	115-120				
	J8-6A	do	8	1	115-120				
	J8-6I	do	8	1	115-120				

Texas:									
Agricultural Experiment Station, College Station.	Lines 5 days earlier than average:								
	33E	Surcropper	7	2	105		150	[14] 100	
	Lines of average maturity:								
	11B	do	7	3	138		110	[14] 150	
	37B	do	7	3	110		125	[14] 90	
	95M	do	7	3	117		120	[14] 125	
	56E	do	7	3	110		120	[14] 125	
	4E	do	7	3	110		95	[14] 95	
	72D	do	7	3	105		120	[14] 125	
	78A	do	7	3	105		100	[14] 150	
	6F	do	7	3	120		125	[14] 100	
	4M-10-1-1-6-1	do	5	1	125		125	[14] 85	
	40A-1R-3-2-9-1	do	5	1	115		105	[14] 125	
	47M-17R-2-5-10-1	do	5	1	112		105	[14] 100	
	Lines 5 days later than average:								
	128B	Mosshart Yellow Dent	6	1	144		150	[14] 125	
	132A	do	6	1	134		100	[14] 80	
	127A	do	6	1	122		150	[14] 125	
	149B	do	6	1	125		125	[14] 150	
	102A	Blue Grain	7	2	133		150	[14] 150	
	108A	do	7	2	133		125	[14] 80	
	105A	do	7	2	126		125	[14] 100	
	106B	do	7	2	120		135	[14] 80	
Virginia:									
Bureau of Plant Industry, Division of Cereal Crops and Diseases:									
Arlington Experiment Farm, Rosslyn.	540	Illinois Two-Ear	10	5	120	120	110	100	2 small, high ears.
	228-4-8	Lancaster Surecrop	15	5	120	120	100	100	1 long, low ear.
	119-11a	Boone County White	15	2	120	110	100		11a and 11b related through 4 generations.
	119-11b	do	15	2	120	110	100		
	119-23	do	15	2	120	80	90		
	119-24	do	15	2	120	70	40		Very poor seed.
	119-41	do	15	2	120	110	100		
	119-43	do	15	2	120	110	100		
	119-61	do	15	2	120	120	90		Difficult to propagate.
	119-62	do	15	2	120	80	100		
West Virginia:									
Agricultural Experiment Station, Morgantown.	Lines of average maturity:								
	1934-2400 (88)	Reid Yellow Dent	14	1	127			99	
	1934-1100 (84)	Leaming	13	1	109			97	
	1934-9100 (96)	Cocke Prolific	15	1	144			98	

See footnotes at end of table.

Table 3.—*Summary of the performance of the outstanding inbred lines developed as a result of the inbreeding programs. The performance of each line in hybrids is expressed as a percentage of the average performance of all hybrids or of the check varieties with which it was compared*—Continued

State, institution, and location	Line	Parent variety	Generations selfed	Performance in hybrids: Years tested	Acre yield	Resistance to lodging	Resistance to moldy ears	Resistance to smut	Other characteristics
			Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	
Ohio—Continued.									
Agricultural Experiment Station, Wooster and Columbus.	Lines 10 days later than average:								
	20	Eichelberger Clarage	15	9	100	80	100	105	Corn borer resistant.
	61	Burr Leaming Double Cross	9	4	110	100	110	90	Long ear, long husk, good-quality grain.
	47	Eichelberger Clarage	10	4	110	90	100	100	Vigorous seedling, large, tall.
	67	do	10	4	110	115	100	100	Heavy pollen producer, long shank, tendency for multiple ears.
	73B	do	10	4	110	100	80	80	Large, thick culm, vigorous, leafy.
	10	do	10	4	115	95	105	100	Excellent line with stiff mates, medium long ear.
South Dakota:									
Agricultural Experiment Station, Brookings.	1210-1	Alta	9	4	128	100	100	90	
	1210-4	Brookings 86	9	4	122	100	100	95	
	1210-7	Reid Yellow Dent	8	3	117	100	100	95	
	1210-13	Wimple Yellow Dent	7	2	142	100	100	90	
	1210-15	Northwestern Dent	8	2	127	100	100	95	
Tennessee:									
Agricultural Experiment Station, Knoxville.[4]	Lines of average maturity:								
	10	Neal Paymaster	5	2	110-120				
	14	do	5	2	110-120				
	43	do	5	2	110-120				
	47-1	do	5	2	110-120				
	74-2	do	5	2	110-120				
	75-2	do	5	1	110-115				
	76	do	5	2	110-120				
	93	do	5	2	110-120				
	2	do	5	1	120-130				
	4	do	5	2	120-130	(13)	(13)	(13)	
	15	do	5	2	120-130				
	47-2	do	5	2	120-130				
	75-1	do	5	1	120-130				
	85-2	do	5	2	120-130				
	102	do	5	2	120-130				
	J5-5	Jarvis Golden Prolific	8	1	115-120				
	J7-2	do	8	1	115-120				
	J8-6A	do	8	1	115-120				
	J8-6I	do	8	1	115-120				

Texas:									
Agricultural Experiment Station, College Station.	Lines 5 days earlier than average:								
	33E	Surcropper	7	2	105		150	[14] 100	
	Lines of average maturity:								
	11B	do	7	3	138		110	[14] 150	
	37B	do	7	3	110		125	[14] 90	
	95M	do	7	3	117		120	[14] 125	
	56E	do	7	3	110		120	[14] 125	
	4E	do	7	3	110		95	[14] 95	
	72D	do	7	3	105		120	[14] 125	
	78A	do	7	3	105		100	[14] 150	
	6F	do	7	3	120		125	[14] 100	
	4M-10-1-1-6-1	do	5	1	125		125	[14] 85	
	40A-1R-3-2-9-1	do	5	1	115		105	[14] 125	
	47M-17R-2-5-10-1	do	5	1	112		105	[14] 100	
	Lines 5 days later than average:								
	128B	Mosshart Yellow Dent	6	1	144		150	[14] 125	
	132A	do	6	1	134		100	[14] 80	
	127A	do	6	1	122		150	[14] 125	
	149B	do	6	1	125		125	[14] 150	
	102A	Blue Grain	7	2	133		150	[14] 150	
	108A	do	7	2	133		125	[14] 80	
	105A	do	7	2	126		125	[14] 100	
	106B	do	7	2	120		135	[14] 80	
Virginia:									
Bureau of Plant Industry, Division of Cereal Crops and Diseases:									
Arlington Experiment Farm, Rosslyn.	540	Illinois Two-Ear	10	5	120	120	110	100	2 small, high ears.
	228-4-8	Lancaster Surecrop	15	5	120	120	100	100	1 long, low ear.
	119-11a	Boone County White	15	2	120	110	100		11a and 11b related through 4 generations.
	119-11b	do	15	2	120	110	100		
	119-23	do	15	2	120	80	90		
	119-24	do	15	2	120	70	40		Very poor seed.
	119-41	do	15	2	120	110	100		
	119-43	do	15	2	120	110	100		
	119-61	do	15	2	120	120	90		Difficult to propagate.
	119-62	do	15	2	120	80	100		
West Virginia:									
Agricultural Experiment Station, Morgantown.	Lines of average maturity:								
	1934-2400 (88)	Reid Yellow Dent	14	1	127			99	
	1934-1100 (84)	Leaming	13	1	109			97	
	1934-9100 (96)	Cocke Prolific	15	1	144			98	

See footnotes at end of table.

TABLE 3.—*Summary of the performance of the outstanding inbred lines developed as a result of the inbreeding programs. The performance of each line in hybrids is expressed as a percentage of the average performance of all hybrids or of the check varieties with which it was compared*—Continued

State, institution, and location	Line	Parent variety	Generations selfed	Performance in hybrids					
				Years tested	Acre yield	Resistance to lodging	Resistance to moldy ears	Resistance to smut	Other characteristics
Wisconsin:									
Agricultural Experiment Station, Madison.[4]	Lines 10 days earlier than average:		*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	
	9	Golden Glow	10	5	110	105	100	100	Dies down early, susceptible to stalk rot.
	25	do	10	5	110	125	110	70	Good stalk, susceptible smut, well anchored.
	M13	Minnesota 13	12	5	115	100	110	70	Good-quality grain.
	CR11	Golden Glow	10	4	100	100	100	75	White cob, shallow kernel, early.
	1553	Kalmoe Minnesota variety	5	2	115	110	110	110	Good stalk and ear quality, breeding material.
	Lines of average maturity:								
	R3	Reid Yellow Dent	12	5	115	125	125	115	Good pollen producer, well anchored, good-quality grain, good stock.
	3	Golden Glow	12	5	115	90	110	90	Weak anchorage, good stalk, large kernel.
	6	do	12	5	115	110	75	110	Susceptible to ear rot, stalks ripen early.
	23	do	12	5	100	100	110	75	Susceptible to ear smut, small kernel, large number of kernels on ear.
	26	do	12	5	110	125	110	70	Very well anchored, good stalk and leafage, susceptible to smut.
	Lines 10 days later than average:								
	Illinois A	Funk Yellow Dent	16	3	120	115	125	115	Good-quality grain, susceptible to stalk rot.
	Illinois B10	do	16	3	110	105	115	100	Variable, limited use.
	Illinois A48	do	16	3	115	110	110	100	115-day maturity, satisfactory quality.
	Illinois Hy	Illinois High Yield	16	2	120	115	125	100	120-day maturity, good-quality grain, susceptible to ear smut.

	Illinois 90	Funk 90-day	----	2	----	110	125	110	120-day maturity, good-quality grain.
	1502	Second cycle inbred (single hybrid).	6	2	----	125	125	105	Very good stalk, breeding material only.
Branch Experiment Station, Spooner.	Lines 10 days earlier than average: G	Wisconsin No. 25	8	2	110	100	110	110	Light-green color, slender stalk, main feature is good height with earliness.
	D	do	11	4	110	90	110	110	Weak anchorage, small kernel, in right combinations a good early corn.
	Lines of average maturity: C	do	11	4	115	115	110	80	Good stalk, very leafy, susceptible to smut.
	F	do	11	4	110	100	110	100	Remains green longer than any others, produces reddish-colored ears.
	Lines 10 days later than average: H	do	8	2	105	125	110	110	Very well anchored, dark-green color, long shank.
	S	do	9	1	----	125	110	100	Very well anchored.

1 So few smutted plants that the differences among lines were of no significance.
2 Synthetic variety B was made up the second year of the project from 13 selfed lines, including 12 first-year selfs and 1 three-year Whatley self from the Georgia College. The purpose was to combine prolificacy and weevil resistance in a breeding stock.
3 Resistance to weevils, smut is not a factor.
4 In cooperation with the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.
5 In cooperation with the Illinois Agricultural Experiment Station, Urbana, Ill., and Funk Bros. Seed Co., Bloomington, Ill.
6 No tillers=100.
7 Second cycle inbreds from single crosses backcrossed once and then inbred 6 generations (self or sib).
8 Obtained from Hi-Bred Corn Co., Grimes, Iowa, in 1930.
9 Obtained from J. R. Holbert, Division of Cereal Crops and Diseases, Bureau of Plant Industry, in 1927.
10 The hybrids in which these lines have been used as one or both parents have yielded from 150 percent to 400 percent of the standard varieties. It should be realized, however, that this performance is based upon a low scale of yields which makes comparisons on a percentage basis misleading. Actual yield increases of 5 to 20 bushels have been obtained.
11 Yield comparisons have been for silage production.
12 Resistance to ear worm damage.
13 No specific evaluation made on resistance to lodging, moldy ears, and smut. All lines are better than the average of the variety.

Table 4.—*Corn hybrids developed by the agricultural experiment stations and distributed for commercial production*

State, distributing agency, and location	Hybrid designation	Kind of cross	Date first distributed	Yield performance: Years tested	Yield performance: Average increase over varieties	Other superior characteristics	Estimated acreage in 1935
				Number	*Percent*		*Acres*
Connecticut:							
Agricultural Experiment Station, New Haven.	Burr-Leaming	Multiple [1]	1922	10	12	More uniform than varieties	500
	Canada-Leaming	do	1930	5	10	Early maturing, can be grown farther north	1, 500
Illinois:							
Bureau of Plant Industry, Division of Cereal Crops and Diseases, Bloomington.[2]	Illinois Hybrid 827 (B × L)×Hy	3-way	1933	5	15	Stands well	1, 600
	Illinois Hybrid 905 (A × L)×Hy	do	1933	5	15	do	2, 400
	Illinois Hybrid 221 (A ×90)×Hy	do	1934	5	15	do	7, 200
	Illinois Hybrid 912 (A × L)×(R4 × Hy)	Double	1933	5	15	do	9, 600
	Illinois Hybrid 392 (A × Hy) × (Indiana Tr × R4)	do	1934	4	20	do	3, 200
Indiana:							
Agricultural Experiment Station, LaFayette.[3]	Hoosier Hybrid 660 (66 × L) × Tr	3-way	1932	5	15	Stiff stalks; good foliage, easy to pick	1, 500
	Hoosier Hybrid 666 (Tr × L) × 66	do	1932	5	12	do	1, 200
Iowa:							
Agricultural Experiment Station, Ames.[3]	Iowa Hybrid 931 (L 289A2 × C1 447A2) × (Os 420C2 × Os 426).	Double	1932	5	18	More resistant to lodging than commercial varieties.	11, 000
	Iowa Hybrid 939 (I 205A1 × L 289A2) × (Os 420C2 × Os 426).	do	1934	4	19	do	25, 000
	Iowa Hybrid 942 (I 234 × L 289A2) × (Os 420C2 × Os 426).	do	1932	5	19	do	42, 000
	Iowa Hybrid 13 (L 317B2 × B1 349A) × (B1 345B × Mc 401).	do	1934	4	26	do	10, 000
Kentucky:							
Agricultural Experiment Station, Lexington.	Double 69 (39 × 21) × (27×30)	do	1935	2	11	Improved market quality	50
Minnesota:							
Agricultural Experiment Station, University Farm, St. Paul.	Minhybrid 301 (11 × 14) × B164	3-way	1934	4	17	Resistance to lodging and smut	11, 000 20, 000
	Minhybrid 401 (11 × 14) × (15 × 19)	Double	1933	10	11	Earliness and resistance to lodging and smut.	15, 000
	Minhybrid 402 (11 × 14) × (16 × 20)	do	1933	10	12	do	15, 000

Nebraska:							
Agricultural Experiment Station, Lincoln.	Nebraska Hybrid 238 (Iowa I 197 × Iowa Os 426) × (Iowa Os 420 × Illinois A).	do	1933	2	16	Resistance to lodging, less suckering	4,200
	Nebraska Hybrid 252 (Indiana 46-12 × Illinois L) × (Iowa Os 420 × Illinois A)	do	1933	2	20	do	
	Nebraska Hybrid 362 (Iowa I 234 × Iowa L 289) × (Illinois A × Illinois L).	do	1933	2	14	do	
New Jersey:							
Agricultural Experiment Station, New Brunswick.	(A12 × A30) × (A21 × A37)	do	1933	4	10-20	Leafiness; resistance to lodging, drought and disease; high weight per bushel.	
	(A12 × A30) × (A47 × A49)	do	1933	4	10-20	do	
	(A30 × A47) × (B42 × A64)	do	1935	3	10-20	do	
New York:							
Agricultural Experiment Station, Ithaca.	29-3 (35-1 × 35-2) × (35-4 × 35-3)	do	1934	5	(4)	Same maturity as best local grain variety and 2 weeks earlier than best commercial silage variety.	1,200
North Dakota:							
Agricultural Experiment Station, Fargo.	(B28 × A10) × (A17 × A28)	do	1933	6	None.	No more productive than varieties but early enough for northernmost sections of the State and tall enough to handle with corn-harvesting machinery.	Small.
Ohio:							
Agricultural Experiment Station, Wooster and Columbus.[3]			(5)				
Wisconsin:							
Agricultural Experiment Station, Madison.[3]	Wisconsin Hybrid 350 (M13 × 9) × 25	3-way	1934	3	18	90-day [6]	360
	Wisconsin Hybrid 404 (M13 × 25) × (9 × R3)	Double	1934	3	18	95-day [6]	750
	Wisconsin Hybrid 406 (M13 × R3) × 25	3-way	1935	3	13	do.[6]	
	Wisconsin Hybrid 450 (M13 × 25) × R3	do	1934	3	18	100-day [6]	700
	Wisconsin Hybrid 455 (3 × R3) × (M13 × 25)	Double	1934	2	13	do.[6]	125
	Wisconsin Hybrid 520 (3 × R3) × (M13 × 6)	do	1933	3	19	105-day [6]	1,800
	Wisconsin Hybrid 525 (M13 × R3) × (3 × 26)	do	1933	3	16	do.[6]	1,300
	Wisconsin Hybrid 530 (M13 × 6) × (23 × 26)	do	1933	2	25	do.[6]	1,000
	Wisconsin Hybrid 550 (3 × 26) × R3	3-way	1933	3	19	110-day [6]	1,800
	Wisconsin Hybrid 555 (6 × R3) × (3 × 26)	Double	1933	3	16	do.[6]	375
	Wisconsin Hybrid 570 (3 × R3) × (23 × 26)	do	1933	3	18	do.[6]	350
	Wisconsin Hybrid 571 (6 × R3) × (23 × 26)	do	1933	2	19	do.[6]	1,950
	Wisconsin Hybrid 601 (R3 × Illinois A48) × (3 × 26).	do	1935	1	25	115-day [6]	25

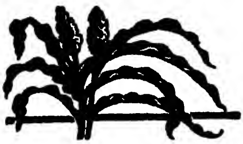
See footnotes at end of table.

TABLE 4.—*Corn hybrids developed by the agricultural experiment stations and distributed for commercial production*—Continued

State, distributing agency, and location	Hybrid designation	Kind of cross	Date first distributed	Yield performance: Years tested	Yield performance: Average increase over varieties	Other superior characteristics	Estimated acreage in 1935
Wisconsin—Continued.				*Number*	*Percent*		*Acres*
Agricultural Experiment Station, Madison.[3]	Wisconsin Hybrid 602 (3 × R3) × (23 × Illinois A48).	Double	1935	2	16	115-day [6]	25
	Wisconsin Hybrid 604 (3 × Illinois A48) × R3	3-way	1935	1	30	do.[6]	25
	Wisconsin Hybrid 605 (Illinois B10 × R3) × (23 × 26).	Double	1934	2	16	do.[6]	1,050
	Wisconsin Hybrid 671 (Illinois A × Illinois A48) × R3.	3-way	1935	2	18	120-day [6]	
	Wisconsin Hybrid 672 (3 × R3) × (Illinois A × Illinois A48).	Double	1935	1	16	do.[6]	
	Wisconsin Hybrid 681 (3 × R3) × (Illinois A × Illinois 90).	do	1935	1	20	do.[6]	

[1] Burr-Leaming was first distributed as a double cross.
[2] In cooperation with the Illinois Agricultural Experiment Station, Urbana, Ill., and Funk Bros. Seed Co., Bloomington, Ill.
[3] In cooperation with the Bureau of Plant Industry, Division of Cereal Crops and Diseases, U. S. Department of Agriculture.
[4] 11 (silage), 35 (grain).
[5] 27 crosses released in 1933 and more than 50 in 1934 for experimental trials. None is in commercial production now, but 10 or 12 will be released in 1936.
[6] Relative maturity class; remains green until ears are mature; relatively free from stalk and ear rots, smut, lodging, and barren stalks.

Sorghum Improvement



By John H. Martin, Senior Agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry

NEW IN THE UNITED STATES, SORGHUM IS AN ANCIENT CROP WITH MANY USES

SORGHUM is a comparatively new crop in the United States, an immigrant, so that there is still an element of novelty about it; but in Africa and Asia it is an old story. A carving on the walls of King Sennacherib's palace in Nineveh, Assyria, built about 700 B. C., showed a field of mature grain sorghum in which could be seen several hogs that perhaps had strayed away from his neighbor's wallow. A mosaic found in 1916 in the ruins of an 1,800-year-old palace in Timgad, north Africa, shows a man reclining on a couch grasping a large head of grain sorghum that would take first prize at any county fair today.

The word sorghum implies "molasses" to most American city dwellers, although less than 3 percent of our crop is used for making sirup. In the dry, hot Southwestern States sorghum is highly appreciated, and it supplies a large part of the grain and forage for livestock. The ability of the plant to remain dormant but uninjured during long periods of drought and then to resume growth when moisture becomes available has caused it to be referred to as the "crop camel."

Coming to the United States from the Tropics of Africa and India practically within the past 80 years, the sorghums are now grown on about 10 million acres annually. Texas, Oklahoma, and Kansas lead in production. The plants are also grown extensively throughout the African continent, and in India, China, and Manchuria, and they are found in Asia Minor, Iran (Persia), Turkestan, Chosen (Korea), Japan, Australia, southern Europe, Central America, and South America.

Sorghums [1] are divided among several different groups that have distinct uses in this country.

The grain sorghums, such as kafir, milo, hegari, feterita, and darso, are grown to furnish feed grain for all classes of livestock, and the stalks are used for forage in the form of fodder, stover, or silage.

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[1] *Sorghum vulgare*, Pers.

The sorgos (sweet sorghums or cane) are grown for forage or for sirup making. Broomcorn is grown for the brush that is used to make brooms. Sudan grass is grown for pasture and hay.

In Africa and Asia sorghums have additional uses. The grain is used for human food in the form of bread, porridge, or confectionery and for making an alcoholic drink resembling beer. The stalks serve for fuel as a substitute for wood, and they are employed for making baskets, furniture, mats, shelter, fences, and toys.[2] Sorghum is useful as a cover in tribal warfare, and doubtless was utilized by the natives in the recent conflict in Ethiopia.

The use of grain sorghum for food is widespread among millions of Africans and Asiatics. The grain is regarded as "coarse" in India

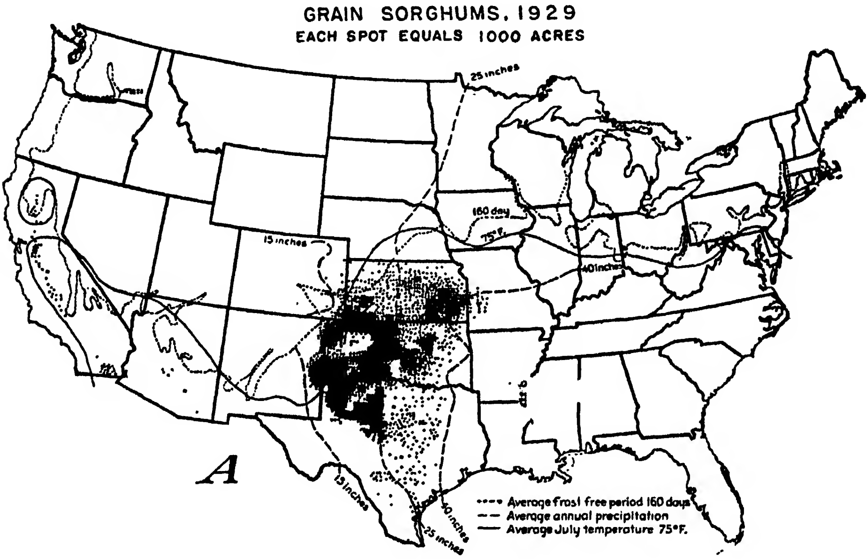


FIGURE 1.

A, Distribution of the acreage of grain sorghum harvested for grain in 1929 in relation to rainfall, temperature, and growing season. Most of the crop is grown where the precipitation is between 17 and 25 inches annually, the average July temperature is 75° F. or higher, and the growing season is longer than 160 days. Where the average precipitation exceeds 40 inches, the drought resistance of sorghum has little advantage over corn and the grain is difficult to dry and keep in storage.

and China, and usually it is consumed by those who cannot afford wheat or rice. In South Africa, the excellent health of the native Bantu children often is ascribed to the kafir mush they eat. After souring for a day and then being recooked, this mush is served to invalids and those with stomach complaints. The United States Department of Agriculture and some of the State agricultural experiment stations have published recipes for making mush, bread, muffins, pancakes, waffles, pudding, doughnuts, cake, and cookies from grain-sorghum meal or flour, but practically nobody in the United States uses them now. Other cereals are preferred. During the drought and the hard times of the nineties in western Kansas, however, when "relief" came only from individual effort, the hardy pioneers frequently relied on kafir meal as their chief food. Grain sorghum is

[2] These sentences are being written with a penholder made in Chosen (Korea) from a sorghum stalk.

not a complete food for either man or beast, as it requires supplementing to make a balanced diet.

Sorgo is grown for roughage on about 3 million acres, mostly in the southern half of the United States. About 200,000 to 300,000 additional acres are grown for sirup. Grain sorghums are grown on 7 million acres or more annually, their greatest value being their resistance to drought and heat (fig. 1). Corn is not well adapted to the semiarid portion of the Southwest, and there the introduced grain sorghums largely take the place of the corn grown in more favorable areas. Grain sorghum also is an important feed crop in the torrid interior irrigated valleys of southern Arizona and California, where it appears to withstand extreme heat better than corn.

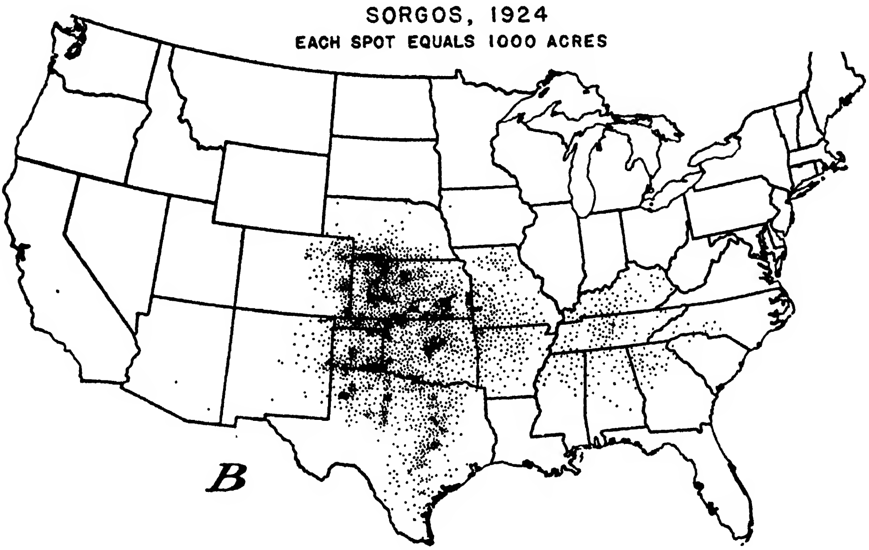


FIGURE 1.

B, The distribution of the acreage of sorgo in 1924 shows that it is grown for forage or sirup less intensively but over a wider area than grain sorghum. Full maturity is not so essential for sorgo and the harvesting and storage problem is less acute.

How Sorghums Came to the United States

The first seed of any kind of sorghum probably was brought to the Western Hemisphere in slave ships from Africa. One variety, called "chicken corn," has escaped from cultivation and become a weed in some of the Southern States. The Dark Continent is believed to be the native home of sorghums and nearly all of the varieties now grown in this country are of African origin or derivation.

With a few exceptions, the sorghums brought in from the wilds of Africa or Asia have required some selection or "taming" to adapt them to modern domestic culture. The selection of desirable variations, hybrids, and mutations during the 80 years of continuous American culture has transformed the partly adapted exotic sorghums into types well suited for the production of grain, forage, or sirup under a wide range of local climatic and cultural conditions. Many of the introduced varieties are too late to mature in our climate and most of them are too tall to be handled conveniently with our harvesting

machinery. The deliberate African or Asiatic native is content to chop down a gigantic stalk laboriously with a knife and then cut off the head. Besides, the large stalks are useful to him for fuel or building purposes. As for late maturity, it does not make any great difference in the long tropical season.

The first sorgo or sweet sorghum was introduced into the United States from France in 1853. The variety brought in, Chinese Amber, had been sent to France from the island of Tsungming in China in 1851. The United States Department of Agriculture distributed large quantities of the seed in this country in 1857. In 1854, Leonard Wray, an English sugar planter in Natal, South Africa, sent 16 varieties of sorgo, which the natives called Imphee, for growing in several countries in Europe. In 1857 these varieties were brought from Toulouse, France, to America by Mr. Wray at the request of Horace Greeley of "go West" fame, and were grown in South Carolina and Georgia under Mr. Wray's personal supervision. The varieties introduced by Mr. Wray under such un-American Zulu names as Vimbischuapa, Oomseeana, Shlagoova, and others included the progenitors and probably the present types of the varieties known today as Orange, Sourless, Honey, Sumac, Gooseneck, and White African.

The Collier variety was selected from a sorgo that was sent from Natal, South Africa, to England and was subsequently introduced from England by the United States Department of Agriculture in 1881. The Planter variety traveled from Africa to India to Australia, and thence to the United States in 1888. In 1891 McLean sorgo also was introduced by the Department from Australia. With these three exceptions, all American sorgos were developed from the Chinese Amber or some of the 16 varieties introduced by Mr. Wray.

The early efforts in sorgo production gave little attention to forage problems or even to sirup making but were concerned largely with the possible establishment of a sugar industry. The investigation of sorghum-sugar manufacture was the chief work of the Division of Chemistry of the United States Department of Agriculture during the eighties and early nineties. Harvey W. Wiley, later famous for his battle for pure foods, devoted most of his research to sorghum-sugar problems for several years after entering the Government service. Attempts to manufacture sugar from sorghum were partially successful but never profitable. After nearly 40 years of national, State, and private effort, including long, elaborate experiments in sugar manufacture, sorgo was discarded as a sugar crop. Meanwhile, the beet-sugar industry had become firmly established.

Our first grain sorghum was the so-called "guinea corn" (Rural Branching durra or White Milo maize) that reached the West Indies in slave ships from Africa. It later entered the United States many years before the introduction of sorgo in 1853, and was rather widely distributed a half century or more ago but has now practically disappeared from cultivation except in some of the West Indian islands. Other grain sorghums came to this country during the colonial period but did not become permanently established. White durra and Brown durra—called Egyptian corn or "Gyp" corn—were introduced from Egypt to California in 1874, and their success was the beginning of our continued and expanding grain sorghum culture. White kafir, and apparently Red kafir, from Natal, South Africa, were shown at the Centennial Exposition at Philadelphia in 1876 and seed from the

exhibit was later distributed in this country. Milo (maize) appeared in South Carolina from an unknown source, probably Africa, in the early eighties. Shallu (Egyptian wheat) was introduced from India by the Louisiana Agricultural Experiment Station about 1890. Pink kafir from South Africa was introduced about 1904, and feterita was brought in in 1906 and hegari in 1908 by the United States Department of Agriculture, from the Anglo-Egyptian Sudan in the upper Nile Valley.

More than 80 distinct varieties of grain sorghum and sorgo are now grown commercially in the United States, all of which have been developed from some of the 20 sorgo introductions and the 8 or 9 grain sorghum introductions mentioned above.

Broomcorn was introduced to the American public during the eighteenth century by Benjamin Franklin, who found a seed in a broom imported from Europe. Sudan grass was introduced by C. V. Piper of the United States Department of Agriculture in 1909. Johnson grass—the perennial relative of the annual Sudan grass—that spreads by underground stems and is regarded more as a weed than as a forage crop, was introduced from Turkey about 1830 by Governor Means of South Carolina. Ten years later the grass was glorified by William Johnson of Alabama; today it is regarded as a curse by thousands of farmers throughout the South.

Characteristics of Sorghum and the Leading Varieties Grown in the United States

THE sorghums of the world include a wide range of types varying in height from less than 3 feet to more than 20. In maturity they range from less than 80 days between planting and harvest to a period so long that some never ripen in the United States. Some varieties have sweet juicy stalks, others are juicy but not sweet, while still others are deficient in both sweetness and juiciness. A planting of several sorghum varieties when ripe presents a kaleidoscopic effect scarcely inferior to that of the best-planned flower garden, the seeds or heads showing many colors that run from white through pink, cream, buff, yellow, red, purple, and brown to black.

The seeds and heads also vary greatly in size and shape. Some sorghums have seeds fully covered by the chaff, even after threshing, but others are more than half exposed while in the head and thresh out completely free from the chaff. In most varieties the heads are erect or leaning, but in others they are thick and heavy and hang down with an air of modesty. An early sorghum variety produces a few small leaves on a slender stalk, but late varieties have many large leaves on a thick stalk. Most of the sorghums often serve as indulgent hosts to hordes of destructive bacteria or fungus and insect pests; but for each parasite there usually is one resistant variety or more than one with some forbidding character that checks the ravages of the disease or insect.

The wide range in characters makes some of the sorghums appear to be scarcely related, although they all crossbreed indiscriminately,

with or without the help of man. Sorghums are about 95 percent self-pollinated in the field, but they will cross readily with any other variety grown in close proximity.

With such a wide display of contrasting characters within even the American varieties, and such ready hybridization, there is no difficulty in obtaining variations that are the joy of the plant breeder and the basis for crop improvement. A cross between widely different sorts frequently produces such a divergent array of characters that the breeder is baffled over what to select as the best. The possibilities in recombining the numerous characters to obtain new varieties are almost unlimited.

The relationship of the classes and groups and some of the leading varieties of sorghum grown in the United States is shown in the following key:

1. Annual sorghums (*Sorghum vulgare* Pers., *Holcus sorghum* L., *Andropogon sorghum* Brot.).
   - A. Sorgo (sweet or saccharine sorghum):
     Varieties: Black Amber, Kansas Orange, Sumac, Honey, Atlas, etc.
   - B. Grain sorghum:
     1. Milo:
        Varieties: Dwarf Yellow, Double Dwarf Yellow, Beaver, Sooner, etc.
     2. Kafir:
        Varieties: Blackhull, Red, Pink, etc.
     3. Feterita:
        Varieties: Standard, Spur, Dwarf.
     4. Durra (Egyptian corn):
        Varieties: White, Brown, Dwarf.
     5. Miscellaneous groups and varieties: Dwarf hegari, darso, Schrock, shallu, Altamont kaoliang, Ajax, Grohoma, etc.
   - C. Broomcorn:
     Varieties: Evergreen, Black Spanish, Scarborough, etc.
   - D. Grass sorghums:
     Varieties: Sudan grass.
2. Perennial sorghum (*Sorghum halepense* (L.), Pers.):
   - A. Johnson grass.

The sorgos are characterized by the production of abundant sweet juice in the stalks. The stalks usually range in height from 5 to 10 feet, and the varieties also differ considerably in maturity. The heads differ widely, according to variety, in size, shape, and compactness. They are either bearded or beardless and have black, brown, or red chaff on the seeds. The seeds are small or medium sized and are either white or some shade of brown.

The grain sorghums differ from sorgos in having less juicy or even comparatively dry stalks at maturity, and the stalk juice is not sweet or is at most only slightly sweet. Grain sorghums, in general, have larger seeds and produce more seed in proportion to total crop than do the sorgos. The stalks of American grain sorghums usually range from 2½ to 6 feet in height.

Among the grain sorghums, kafirs (kafir corn) in general have thick and juicy stalks, relatively large leaves, and beardless cylindrical heads. The seeds are white, pink, or red and of medium size. The chaff is either black or straw-colored. Kafirs are grown for both grain and forage.

Hegari, frequently called "high gear," is similar to kafir in appearance except that the heads are more nearly oval, the seeds are a chalky or starchy white, and the more abundant suckers and leaves make it more prized for forage.

Milos have slightly smaller leaves and stalks than kafir and are less juicy. The leaves have a yellow midvein. The heads of the true milos are bearded, short, compact, and rather oval in outline, with very dark brown chaff. The seeds are large and are yellow or white. The plants sucker considerably, and in general are earlier and more drought-resistant than those of kafir. Milo is grown strictly for grain and the stover usually is not utilized except for pasture.

Feterita has few leaves, slender, relatively dry stalks, rather oval, compact heads, and very large chalky white seeds. Its earliness permits it partly to evade drought and makes it suitable for later planting than kafir. It is grown chiefly as a late-planted catch crop for grain.

THE *selection of desirable variations, hybrids, and mutations during the 80 years of continuous American culture has transformed the partly adapted exotic sorghums into types well suited for the production of grain, forage, or sirup under a wide range of local climatic and cultural conditions. . . . With such a wide display of contrasting characters within even the American varieties, and such ready hybridization, there is no difficulty in obtaining variations that are the joy of the plant breeder and the basis for crop improvement. A cross between widely different sorts produces such a divergent array of characters that the breeder is baffled over what to select as the best. The possibilities in recombining the numerous characters to obtain new varieties are almost unlimited.*

Shallu has tall slender dry stalks, loose heads, and pearly white seeds. It is relatively late in maturity and is grown largely for grain.

The other American grain sorghums are the result of hybridization between different groups of grain sorghums or sorgos and represent combinations of characters of the varieties from which they originated.

Broomcorn produces heads with fibrous seed branches, 12 to 36 inches long, that are used for making brooms and whisk brooms. The tops of hurdles vaulted by racing dogs often are constructed of broomcorn. Long, coarse broomcorn fibers are used to make the stems of many artificial flowers. Broomcorn stalks range from 3 to 14 feet in height and are dry, not sweet, and of limited value for forage. The heads are bearded and fuzzy with small brown seeds enclosed in tan, red, or dark-brown chaff.

Sudan grass has slender leaves and stalks and loose heads with small brown seeds enclosed in dark-tan chaff. Both broomcorn and Sudan grass cross readily with other sorghums.

Johnson grass is similar to Sudan grass except that it is a perennial with underground stems. It crosses occasionally with Sudan grass and other sorghums, but since it has 20 instead of the usual 10 pairs of chromosomes, only part of the crosses are fertile.

EXPERIMENTING WITH FOREIGN INTRODUCTIONS

The United States Department of Agriculture has introduced more than 1,000 lots of sorghum seed during the past 40 years. Most of these have come from China, Manchuria, India, and various parts of Africa. Those from China and Manchuria are practically all of the group known as "kaoliang," meaning "tall millet." Most of the kaoliangs are tall, with dry, woody, slender, sparsely leaved stalks, and a majority have bitter-tasting brown seeds. They have not compared favorably in forage value or grain production with American varieties and although distributed to hundreds of growers cannot now be found on American farms. The few kaoliang characters most useful in breeding American sorghums, such as earliness, ability to grow under cool conditions, and stiffness of stalk, are found in several varieties that have been grown in experiments for many years since their introduction.

The sorghums introduced from India are mostly of the types known here as durra and shallu. Usually they are too late in maturity or have other objectionable characters, such as dry stalks, seed shattering, or excessive height, that make them inferior for American culture. A variety of shallu is the only sorghum introduced from India that is grown in the United States, and this is largely limited to the Gulf section of Texas and Louisiana. Shallu has few characters desired in American sorghums with the exception of its attractive pearly seed of high protein content and its resistance to "red spot" diseases.

Many of the Indian sorghums are the type classed as durra in the United States. Durras have bearded, fuzzy heads, large flat seeds, and dry stalks. They are the principal sorghums of Persia (Iran), Turkestan, Arabia, and the countries of Africa bordering upon the Mediterranean Sea. Only three varieties of durra are grown in the United States and these are grown almost exclusively in California, where two white-seeded varieties have a ready market in commercial poultry centers. These varieties are especially adapted to the Sacramento Valley but are less productive than milo, hegari, or kafir in all other sections of the country. Foreign durras from the countries mentioned above appear to offer little of value for improving our domestic sorghums. A few varieties have been maintained as a basis for possible breeding or other studies.

Central African tropical sorghums are nearly all too late or too tall for use in the United States and only rarely does one of these mature here (fig. 2).

Varieties recently introduced from South Africa usually are adapted to the sorghum region of the United States, but they have not been equal to the domestic varieties developed from the introductions of sorgo from South Africa in 1857 and kafir in 1876. Feterita and hegari from the Sudan proved to be adaptable to culture in America with only a limited modification by selection.

It has not been feasible to maintain cultures of all the hundreds of the Department's sorghum introductions, but among those that matured seed, the varieties possessing new characters and representa-

FIGURE 2.—A typical tropical sorghum from Ethiopia, 13 feet tall and still growing 4 months after planting but not even starting to head. Sorghums from India and central Africa usually are too late and tall for the American farmer.

tives of each important group have been continued for observation and with the expectation of using them in crossing.

The varieties of sorghum already grown in the United States possess numerous characters that can be used by suitable crosses for most of the needed sorghum improvements.

The Chief Objectives in Breeding for Sorghum Improvement

SORGHUM usually has been bred for either higher yields or better quality. Peculiarly, it is probably one of the few crops that may yield too much.

Many crosses between grain sorghum varieties show extreme vigor in the first hybrid generation. This excessive vigor favors high potential yields, but the hybrids are too tall to be harvested conveniently, frequently they are too late to reach maturity, and they often exhaust the soil moisture before grain is produced. The tall late natural hybrid plants—sometimes called "high birds"—in farmers' fields are very objectionable. Several of the highest-yielding sorgos have stalks so tall and heavy that they are difficult to harvest, shock, haul, stack, and feed. Consequently many farmers prefer

FIGURE 3.—A field of Double Dwarf Yellow milo near Merced, Calif., yielding 120 bushels per acre. This rather new very dwarf variety, the leading sorghum in California, is suitable for harvesting with a combine.

to grow more acres of shorter, lower yielding varieties that are easier to harvest and handle.

Several sorghums now have a potential capacity for very high yields. Milo has produced yields of more than 180 bushels of grain an acre on small tracts of rich irrigated land (fig. 3). Drought, short seasons, poor soil, poor tillage methods, soil washing, diseases, or insects, however, have been instrumental in keeping the average yield of milo in the United States below 15 bushels an acre. Tall, late-maturing sorgos may readily produce 8 tons of cured fodder an acre under favorable conditions. Larger yields than that surely are hard on the land.

Most of the sorghum-improvement work now under way is devoted to some of the following objectives: (1) Earlier maturity; (2) white or yellow palatable seed; (3) dwarf types for easy machine harvesting; (4) insect resistance; (5) smut resistance; (6) resistance to leaf-spot

diseases; (7) resistance to seed and root rots; (8) improved forage quality; (9) resistance to lodging; (10) drought resistance; (11) better sirup production; (12) resistance to cool temperatures; and (13) lower prussic acid content.

Improvements in resistance to diseases, insects, drought, or cool temperatures, or in hybrid vigor or earlier maturity, should result in larger or more stable yields. The other improvements mean better utilization or more economical production.

Strains of Black Amber sorgo, particularly the Dakota Amber, are early enough for growing in any section of the United States that is warm enough for satisfactory corn production. The common varieties of grain sorghums, on the other hand, are too late to be counted on to mature safely in the northern and western portions of the Great Plains region. Early-maturing varieties are needed when moisture is limited and when it is necessary to plant late where other crops have failed, or where double cropping is feasible by planting after the small-grain harvest.

Seeds of all brown-seeded sorghums contain a bitter, puckery, or astringent, tanninlike substance that makes them less palatable to livestock or poultry than white-, yellow-, or red-seeded varieties. Wild birds regularly show a preference for white-seeded sorghums. In South Africa, where injury by birds is very common, many farmers are forced to grow a brown-seeded variety to avoid damage to the crop. In the United States, the brown-seeded sorghums, although nutritious, make the mules forced to eat them discontented and are popularly reputed to dry up cows. The grain brings a lower price on the market than that of the varieties with more palatable seed. Most of the sorgo varieties have brown seeds that have only a limited value except for planting. In consequence, much effort is being devoted to breeding strains that lack the "dark-brown taste" characteristic of certain productive varieties. This is done by crossing them with white-seeded varieties and selecting from the segregating hybrids types with white, yellow, or red seeds but otherwise similar to the brown-seeded parent (fig. 4).

BREEDING FOR MACHINE METHODS OF HARVESTING

Grain sorghums are harvested successfully with combines or headers used in harvesting wheat if the stalks are not more than 4 feet tall, are not lodged, and have erect heads. This has lead to developing varieties that may eliminate the slow and arduous hand-harvesting methods (fig. 6).

Chinch bugs frequently destroy a sorghum crop when a highly susceptible variety, like milo, is planted near a field of wheat or barley infested with the bugs. After the wheat or barley is harvested, the bugs crawl or fly to nearby sorghum fields and destroy the young plants. Most varieties of kafir and many sorgos have considerable resistance to chinch bug injury and these are being used as a basis for the development of resistant strains of milo and other susceptible sorghums (fig. 5).

Varieties resistant to smut, leaf spot, root rot, and seed rot escape the serious losses and eliminate the uncertainty in productien that frequently result from these diseases. Resistance to disease is being attained by selection of disease-free plants or by crossing with other varieties that have demonstrated their resistance.

FIGURE 4.—A field of Atlas sorgo near Manhattan, Kans. This is a dual-purpose sorghum having strong, sweet, juicy stalks and palatable white grain, selected at the Kansas Agricultural Experiment Station from a hybrid between the brown-seeded Sourless sorgo and the white-seeded, strong-stalked Blackhull kafir. It is a popular variety in Kansas, Nebraska, and Missouri, where it is grown for silage and forage. The threshed seed can be sold or fed as kafir grain.

The most palatable forage sorghums are leafy and juicy and the juice is sweet. Certain productive varieties require improvement for one or more of these features to reduce the waste of stover rejected by animals. Harvesting of lodged sorghum is so laborious and wasteful that stronger stalks than some varieties possess are highly desirable. Early-maturing, sparsely leaved sorghums are able partly to evade loss from deficient moisture, particularly if grain is desired. Some varieties of kafir show extreme resistance to wilting during a drought, but often they are so late in resuming growth after rains occur that they fail to produce mature grain. The combination of drought evasion and drought resistance is a desired objective. Sorgos differ materially in both yield and quality of sirup, and further improvement might increase the use of the much-neglected but locally important sorghum sirup, usually called cane sirup or molasses.

Since they are of tropical origin, sorghums develop best in a warm sunny climate. Some varieties, however—particularly those from

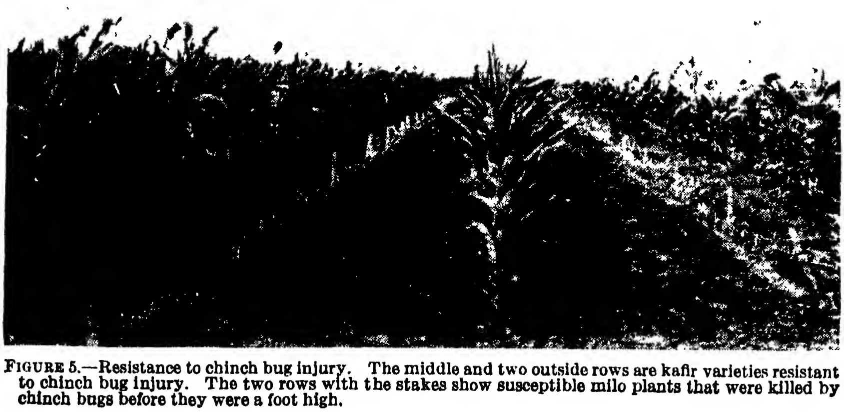
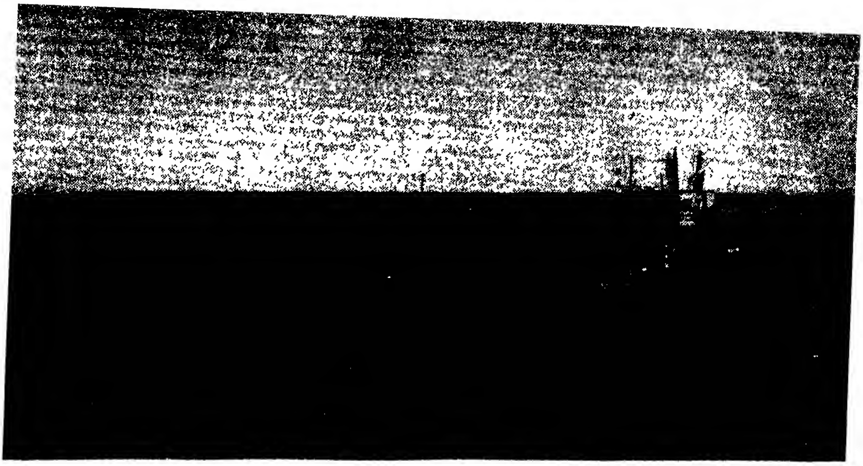


FIGURE 5.—Resistance to chinch bug injury. The middle and two outside rows are kafir varieties resistant to chinch bug injury. The two rows with the stakes show susceptible milo plants that were killed by chinch bugs before they were a foot high.



'IGURE 6.—A dwarf, erect-headed milo developed by the United States Department of Agriculture for harvesting with a combine. It was selected from a hybrid between kafir and milo.

Manchuria and northern China—are able to mature in this country as far north as North Dakota in warm seasons. The yield and quality of these varieties unfortunately leaves much to be desired. Crossing of the northern varieties with more productive grain and forage types promises to improve the sorghums suitable for the northern and western borders of the sorghum region.

The selection of sorghums producing a lower content of the cyanogenetic glucoside that under certain conditions forms the highly poisonous prussic acid has been attempted recently. The plants usually are more dangerous when frosted, stunted by drought, or making a second growth. Sorghum poisoning is relatively infrequent except in the Northern States, but when it occurs it is extremely disastrous to a farmer's herd. Fermented silage and well-cured fodder are practically free from danger.

Sorghum has been crossed with sugarcane in India, Java, Formosa and Florida. The object, aside from the scientific interest of such a wide cross, is to produce an earlier sugar cane adapted to more northern sections, or possibly one that will produce seed regularly in the United States.

The Story of the Development of Improved Sorghum Varieties in the United States

AS IN the case of other crops, improvement in sorghums has been accomplished by plant introductions, selection, and hybridization. The introduction of the 20 varieties of sorgo, 2 of durra, 3 of kafir—including "Guinea corn"—and one each of milo, shallu, feterita, and hegari, that form the basis of our present sorghum crop has already been mentioned. Many more of the hundreds of more recent introductions might have succeeded had they not had to compete with varieties as good or better that were already here.

Several varieties of kaoliang from China and Manchuria and some kafirs from South Africa were distributed to farmers but did not become permanently established. A second introduction of hegari from the Sudan, brought here in 1924, has outyielded the earlier introduction slightly in experiments, but in general is very similar to the older type. Further improvements by introduction are possible, although the opportunities probably are more limited than through hybridization.

The pioneer sorghum breeder in the United States was Peter Collier, formerly chief chemist of the Department of Agriculture, who began extensive selection and analyzing of sorgo varieties about 1880. This work was continued by Harvey W. Wiley, A. A. Denton, and others of the Department, and by G. H. Failyer and J. T. Willard, chemists of the Kansas State Agricultural Experiment Station, and others. The improvement of grain sorghums in this country began in the Department about 1903 and was continued for some years under the supervision of men still active in other fields of agriculture, including A. H. Leidigh, C. R. Ball, A. B. Conner, and H. N. Vinall.

The frequency of natural crossing in sorghums has necessitated the selection of seed heads in nearly all sorghum experiments to keep the varieties pure. A crop from bulk seed always contains some mixtures or hybrids that must be eliminated by selection and purification. Consequently nearly every sorghum variety grown by an experiment station has undergone some selection before it was distributed. In many cases nothing more than seed purification has been accomplished, but in others there has been some definite improvement. The uncertainty of this situation makes it difficult to give proper credit in all cases to those who have been instrumental in improving the sorghums.

The improved varieties of sorghum developed by the United States Department of Agriculture and the State experiment stations, showing their breeding history and their points of superiority, are given in table 4 (p. 558).

The greatest progress in the improvement of sorghums by selection and hybridization has not been in increasing yields, but in developing varieties that can be harvested and cared for more easily and economically, and varieties that are more palatable for livestock. Thus in eliminating back-breaking tasks and in pleasing the animal palate, the plant breeder has helped to make possible "a more abundant life" for both the farmer and his patient beast.

MILO

The improvement of milo probably is the most striking and dramatic accomplishment in sorghum breeding. No less than five distinct new strains have appeared fortuitously on farms during the past 30 years, and additional progress has been made by crossing milo with kafir varieties.

The original milo in this country, the Standard yellow variety, usually grew 6 to 9 feet tall and frequently contained hybrids even taller. Most of the heads were more or less goosenecked or bent over and this resulted in great irregularity in height. Harvesting with machinery was difficult and the heads often were out of reach of a short man who followed the common method of harvesting by cutting them off. The variety apparently mutated or "threw a sport" at

some undetermined time, producing a dwarf plant ranging from 3 to 6 feet in height. The man who first isolated the dwarf type is not known, but the dwarf milo was being grown on a few farms in Texas and Oklahoma as early as 1905. The Department of Agriculture and the Texas Agricultural Experiment Station immediately recognized its advantages, obtained seed, and purified and distributed it as Dwarf Yellow milo shortly thereafter. In a few years the new plant had largely replaced the taller standard type and is now second in importance among the grain sorghums.

Not many years later a Dwarf Yellow milo plant also just as mysteriously lost part of its height, apparently through a mutation. The Double Dwarf or Extra-Dwarf variety seems to have been first isolated in Arizona and to have been sent to the Imperial Valley in

SEVERAL *sorghums now have a potential capacity for very high yields. Milo has produced yields of more than 180 bushels of grain an acre on small tracts of rich irrigated land . . . Tall, late-maturing sorgos may readily produce 8 tons of cured fodder an acre under favorable conditions . . . However, the greatest progress in the improvement of sorghums by selection and hybridization has not been in increasing yields, but in developing varieties that can be harvested and cared for more easily and economically, and varieties that are more palatable for livestock. Thus in eliminating back-breaking tasks and in pleasing the animal palate, the plant breeder has helped to make possible "a more abundant life" for both the farmer and his patient beast.*

California, where officials of the California Agricultural Experiment Station discovered it in 1918. It was purified and distributed by that station shortly thereafter. This variety usually is 2 to 3½ feet in height except under extreme conditions. The Double Dwarf milo is the leading sorghum in California, where it is still short enough to be harvested readily with a combine or by hand, despite the stimulated growth caused by the rich soil, abundant irrigation, and climate of California. The Standard, Dwarf, and Double Dwarf varieties of milo appear to be practically counterparts of each other except in the length of joints in the stem.

Milo Continues to Mutate

Still milo continued apparently to mutate under the influence of southwestern sunshine, hot winds, cosmic rays, "static," or some

other of nature's mysterious forces. A Standard White milo appeared on farms in Texas that differed from the original yellow strain only in the color of the seed, which is controlled by a single hereditary factor. Later a Dwarf White milo was found in Oklahoma, a duplicate of Dwarf Yellow milo except in seed color. Following this, plant breeders of the Texas Agricultural Experiment Station produced a Double Dwarf White milo by hybridization, just to complete the series of types.

These new types are described as probable mutations rather than natural hybrids on the basis of circumstantial evidence. Apparently each new type as it appeared differed from the parental type by a single character or factor. This is the kind of change that is characteristic of mutation rather than hybridization. As partially corroborative evidence, it may be added that at least one mutation, the loss of a height factor, similar to the changes that occur under natural conditions, has been observed in experimental sorghum nurseries and has been brought about by X-ray treatment.

All of the above varieties mature at practically the same time. An earlier variety was needed for late planting, short growing seasons, and dry years. Again nature brought forth the desired character, and it was soon isolated by some observing but unknown and unsung Texas farmer. But the Early White milo—called by farmers Ninety-Day, Sugar, or Little Sweet Maize—is not particularly desirable except for its earliness, since it is too tall, is very subject to lodging, and has white seed, which is less popular than yellow.

Plant breeders of the Department of Agriculture and the Texas Agricultural Experiment Station tackled the problem of improving it. Three breeders working independently crossed Early White milo with Dwarf Yellow milo, and from the progeny each selected an early dwarf yellow type that was nearly but not quite identical with the other two. The first one, produced by J. B. Sieglinger at the United States Department of Agriculture, Southern Great Plains Field Station, at Woodward, Okla., was named Sooner because it was originated in the Sooner State and it matured sooner than any other yellow milo. Sooner milo was given to a few farmers for trial in Oklahoma, Kansas, and Colorado about 1930 (fig. 7). It was found not to equal Dwarf Yellow milo in yield under good growing conditions, and it lodged much more easily after maturity.

However, during the dry years that followed its distribution, Sooner frequently produced grain down in America's "dust bowl" where the later Dwarf Yellow variety used up the available soil moisture or was caught by frost before the grain could develop. It found favor with farmers when they were forced to plant late because of the failure of other crops or when abundant summer rains permitted the double cropping of land from which a small-grain crop had been harvested. The earlier maturity of Sooner has made possible an extension of the area where milo can be grown into more northern latitudes, higher altitudes, and drier sections. A limited local distribution also was made of the two early yellow milos very similar to to Sooner that were developed at the Chillicothe and Lubbock substations of the Texas Agricultural Experiment Station.

Sorghum breeders still were not satisfied. Except in dry seasons, all of the milos just mentioned produce recurved or crook-neck heads unless planted thickly. These crooked heads interfered with clean harvesting by either hand or machine methods. The heads were

FIGURE 7.—Pygmy milo (*A*), Sooner milo (*B*), and Dw[illegible]o (*C*). Note the greater leafiness of the Dwarf Yellow variety that is associated with later maturity. Pygmy and Sooner are early-maturing selections from a hybrid between Dwarf Yellow milo and Early White milo. They are as early as the Early White parent, shorter than either parent, and have the yellow seed of the Dwarf Yellow variety. Pygmy has very short stalks and nearly erect heads, making it adapted to harvesting with a combine.

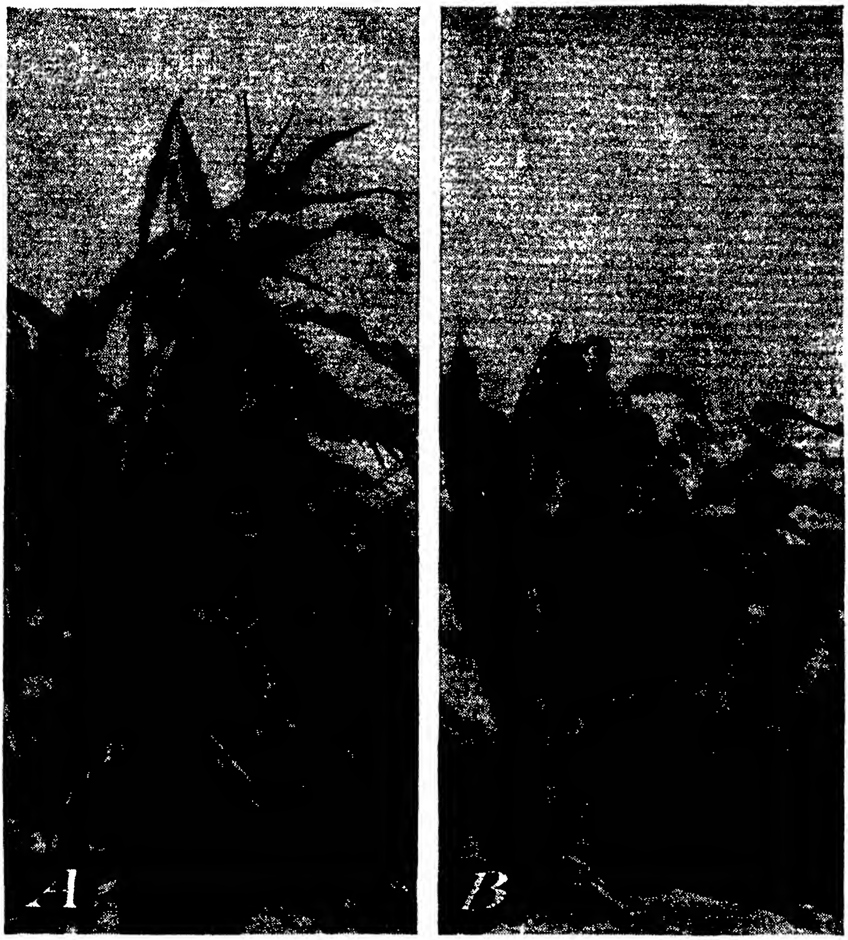


FIGURE 8.
Beaver (*B*) and Wheatland (*C*) developed from hybrids between Dwarf Yellow milo (*A*), and Blackhull kafir (*D*). The new varieties are shorter than either parental variety.

irregular in position, depending on whether they were recurved or not. Heads on crooked stems frequently were caught by the reel on the header or combine and tossed up in the air, to fall on the ground instead of on the cutting platform. It was apparent that an erect-headed or straight-neck variety was needed. Years of continuous selection with this object had proved futile. Hybridization of Dwarf Yellow milo with kafir, however, brought quick results, not only in plants with erect heads but in plants that were much shorter than either parent.

Development of the Wheatland Variety

From a kafir-milo hybrid that in the first generation was taller and later than either parent, J. B. Sieglinger of the United States Department of Agriculture subsequently selected a "combine" variety called Wheatland that was earlier than the kafir and much shorter than either parent. It was named Wheatland because it was adapted

FIGURE 8.

The new varieties have the erect heads of the kafir parent and the large yellow grain and many of the plant characteristics of the milo parent. Short, erect-headed milos are suitable for harvesting with a combine.

... Southwest to replace some

land in southwestern Kansas and ... ern Oklahoma.

Wheatland is not perfect despite its great popularity. It blasts badly so that it does not set seed well when it comes into heading during a severe drought. The yellow grain is more pale and dull than that of other milos, and it is not favored by distributors of mixed feeds in which yellow milo is introduced to give the mixture a rich yellow color. Like other milos, it is highly susceptible to chinch bug injury.

A sister selection of Wheatland was crossed back to the milo parent to obtain a combine type with heads and grain more nearly resembling Dwarf Yellow milo. A selection from this backcross resulted in the variety Beaver, which has compact heads and bright yellow

grain and was also produced by Mr. Sieglinger at Woodward, Okla., not far from the banks of Beaver Creek. Beaver was distributed in 1928 and is still competing with Wheatland for favor as a combine milo. At the time these hybrids were selected, most of the wheat was cut with headers in the grain sorghum region, and combines were scarcely known. Within 2 years after combines were in general use, Beaver was available for distribution.

Wheatland and Beaver (fig. 8) mature on the average in about the same period as Dwarf Yellow milo. An early variety for combining appeared to be needed. Selections of very dwarf erect-headed plants in the cross from which Sooner was selected seem to be of the desired type, and several new varieties are being tested at a number of experiment stations. Two of these, named Day and Pygmy, are especially promising, but others are on the way and should be available by the time growers realize that such varieties have been produced and are ready to demand them.

A New Variety, Resistant to Root Rot

About the time the combine milos were developed, a new disease, a destructive Pythium root rot, began to show up in milo. The disease was discovered at the Garden City (Kans.) Branch Experiment Station. All true milo varieties, including the hybrids mentioned above, were susceptible to the disease. F. A. Wagner, superintendent of the Garden City station, however, noticed some plants that escaped injury. By selecting the healthy plants, he has produced resistant strains of Dwarf Yellow milo and also of Beaver, Wheatland, and Day. The resistant Dwarf Yellow strain already is available for distribution to farmers, although very few have as yet recognized that their troubles in growing milo are in part due to a disease.

The story of milo improvement is not quite complete. A kafir-milo hybrid, named Kalo, was produced at the Fort Hays branch of the Kansas Agricultural Experiment Station by A. F. Swanson, of the United States Department of Agriculture. This variety is productive and has shown ability to yield well north of the regular milo-producing section, but so far it is grown on a very limited scale. It resembles both the kafir and the milo parents in different characters. Swanson later selected the Early Kalo variety from Kalo.

A farmer, H. Willis Smith, formerly of Garden City, Kans., produced a kafir-milo hybrid that is taller and later than either parent and has typical yellow milo seeds but erect, loose heads. This variety—first named Buff kafir but since called Fargo or Straightneck milo—formerly was widely grown in southwestern Kansas and northwestern Oklahoma but has largely lost its popularity because of its lateness and tendency to lodge. It has produced very high yields under irrigation in southern Arizona, but the excessive height and lateness under these conditions may prove seriously objectionable.

Much remains to be done in milo improvement, particularly in securing strains resistant to chinch bug injury and to lodging after maturity. These problems are being attacked vigorously at the present time.

KAFIR

Both of the original kafir varieties introduced in 1876 have some objectionable features. White kafir has a rather dry stalk that

affects its palatability for forage, and the heads usually are partly enclosed in the boot, where they are subject to molding. New varieties free from these drawbacks practically eliminated White kafir from cultivation. Red kafir was late in maturity and consequently not well adapted to the drier western portions of the grain-sorghum region or the northern portions where the season is short. Selection on farms where earlier maturing plants were observed has produced several strains, now widely grown, that are better adapted to most of the kafir region than is the imported type. The Department is now purifying an extremely early drought-resistant Red kafir found growing at altitudes of about 5,000 feet in New Mexico. Blackhull kafir appeared rather mysteriously in cultivation about 1895 and was taken in hand by the Kansas Agricultural Experiment Station for purification and distribution. This variety is now the leading variety of grain sorghum and is admirably suited to the eastern half of the grain-sorghum region but is not sufficiently early or drought-evasive for the western plains.

In 1904 A. H. Leidigh, of the United States Department of Agriculture, began to select kafir for earliness, dwarfness, and drought resistance. Two years later he found a plant—apparently a product of natural hybridization—the progeny of which were uniformly early but were a mixture of both tall and dwarf plants. Continued selection of this material by C. R. Ball resulted in two early, drought-resistant varieties, Dawn or Dwarf kafir, with short stalks, and Sunrise, a taller variety, that were later distributed widely.

Dawn proved to be an excellent kafir for the southern Great Plains region, its earliness favoring the production of grain in short seasons or under conditions of limited moisture where the ordinary Blackhull kafir was likely to fail. The short stalks made harvesting relatively easy. The Sunrise variety produced as much grain as the Dawn, its greater tillering ability seeming to be somewhat advantageous. Sunrise also had several characters desirable from a forage standpoint. The tall, slender, numerous stalks gave a higher yield of stover, and they were sweeter than those of Dawn.

Natural selection also was occurring on the farms in the dry western plains. From the Blackhull kafir there gradually evolved a type that was very similar to the original variety but was slightly shorter and earlier. This new type came to be widely grown although not always in a pure condition. Workers in the United States Department of Agriculture and in the Texas and Kansas Agricultural Experiment Stations selected heads in farmers' fields and purified the best type before distributing it.

From these efforts there are now available several excellent strains of kafir that are practically identical in appearance, behavior, and yield. The strain developed in cooperative experiments at the Fort Hays (Kans.) Branch Experiment Station is called Western Blackhull. The one selected by R. E. Karper at Texas Substation No. 8, Lubbock, is called Texas Blackhull. Two strains isolated at the Department's field station at Woodward, Okla., are called Sharon and Santa Fé kafir. The strains at the Chillicothe and Dalhart field stations in Texas were called Dwarf kafir. This type of kafir has yielded higher than Dawn in most seasons and has largely replaced it on farms. Apparently, however, it is not quite so well suited to severe conditions, where the greater earliness of Dawn is advantageous.

A sample of some kafir imported by the Department was sent to a farmer in Russell County, Kans., about 1905. The Fort Hays Branch Experiment Station secured seed from the crop and began selecting superior heads. From one of the selections that station, in cooperation with the Department, developed what was later named Pink kafir because of the color of the seed. This variety was somewhat earlier than Blackhull, and until the appearance of Western Blackhull was widely distributed and highly prized in western and central Kansas, particularly as a combination forage and grain in the form of "bundle feed."

Other kafirs have appeared on the southwestern plains that have certain real or apparent virtues to distinguish them. Pearl and Rice kafir have attractive seeds but otherwise are not superior to Blackhull. Reed kafir, selected by an Oklahoma farmer, has shown high yields of grain in Oklahoma and Texas although it lodges easily and tends to lose its leaves at maturity. Hydro kafir was developed near Hydro, Okla., from the same material as the Reed variety. Its chief merit is its large, compact, well-filled, square-tipped heads when grown under favorable conditions. Because of these, the variety wins most of the prizes for exhibits of kafir heads at local fairs. Bishop kafir (Algeria) has large bushy heads that attract attention and produce good yields under favorable conditions. It apparently is a selection from a kafir-milo hybrid.

FETERITA

The original feterita introduced from Khartoum, Sudan, in 1906 proved to be something of a mixture of types. The predominating type was selected for distribution by H. N. Vinall and A. B. Conner at Chillicothe, Tex. Later this was subjected to further selection at the Fort Hays (Kans.) Branch Experiment Station. The mixed material was sent to Texas Substation No. 7, at Spur, and many types were isolated there by R. E. Dickson, superintendent of the experiment station. Two of these, named Spur and Dwarf feterita, were later distributed. These strains have less pointed heads and are later and usually more productive under good conditions than the type isolated and generally grown in Kansas. Spur feterita has thus far proved immune to all physiologic forms of sorghum smut.

DURRA

Durra was grown rather widely in Kansas under the name Jerusalem corn during the nineties, but during the last 30 years its culture has been so largely limited to a small part of California that little effort has been given durra improvement. C. R. Ball isolated an erect but open-headed strain from the compact-headed crooknecked White durra at Amarillo, Tex., but it did not become established commercially after distribution. Several erect-headed durras have been introduced from foreign countries since that time, but they also have undesirable open or loose heads and are not superior to the old White durra in yield. Recurving or crooknecking is caused by the fact that thick, compact, heavy heads are forced out of the side of the boot during heading and bend down from their own weight. Heads of this type cannot remain erect.

The only improved durra in this country is the Dwarf White variety originated by Hoeffling Bros., of Chico, Calif., and distributed by

them about 1929. This variety usually is short enough to be harvested with a combine. The original White durra usually attains a height of 7 to 9 feet under good irrigation and is too tall even for convenient hand heading.

KAOLIANG

Selection of kaoliangs, usually for earlier maturity, was attempted in Texas, Colorado, South Dakota, and other States. One strain, isolated in cooperative experiments in South Dakota and named Altamont, is somewhat earlier and more productive in that State than the original Manchu Brown variety. It has been grown only sparingly because in much of the State corn, or Dakota Amber sorgo, is preferable.

MISCELLANEOUS GRAIN SORGHUMS

The first planned artificial grain sorghum crosses made by investigators in this country apparently were those of H. N. Vinall and A. B. Cron, of the Department of Agriculture at Washington, D. C., and Amarillo, Tex., in 1914. Selections made from one of these crosses, Feterita × Blackhull kafir, resulted in the production of two varieties, Chiltex and Premo. They were developed and distributed, in cooperation with the Texas Agr cultural Experiment Station, from substation No. 12, at Chillicothe. Chiltex is now grown to a considerable extent in Oklahoma and Texas, where it has largely replaced kafir in some sections because of its superior drought resistance.

Premo was crossed with Spur feterita by Mr. Vinall about 1923, and a selection from this cross made at Chillicothe, Tex., by J. R. Quinby and J. C. Stephens resulted in a productive variety, Ajax, that was first distributed about 1930. Ajax has become very popular in the black lands of Texas.

Greeley sorghum was selected by J. H. Parker and T. B. Stinson from a natural hybrid between Pink kafir and Freed sorghum. The selections were made and tested at the Tribune (Kans.) Branch Experiment Station. This variety, first distributed about 1932, provides a crop suitable for grain or forage that usually matures grain under the dry conditions and in the short season in extreme western Kansas.

Sorghums cross-pollinate so frequently that fields entirely free from natural hybrids are rarely seen. The hybrid plants often appear to be so very productive that they are saved and increased by farmers. Most of them are discarded after brief trials because of failure to substantiate their earlier promise, or they continue to break up into numerous types, many of which are undesirable. Occasionally, however, a new worth-while variety is developed from a chance hybrid.

A new grain sorghum variety with reddish-brown seeds was found on a farm in Oklahoma about 1912. The Oklahoma Agricultural Experiment Station obtained seed, made some additional selection, and distributed the variety under the name "darso" (a contraction of the words "dwarf red sorghum") about 1914. Darso has proved rather resistant both to drought and chinch bug injury and is well adapted to the central portions of Kansas, Oklahoma, and Texas, where it is now grown. The reddish-brown seeds partly prevent bird injury, but the grain also is less palatable to livestock and poultry. Sorghum breeders have since developed white-seeded and yellow-seeded strains that are very similar to darso but have a higher palat-

ability. Some of these strains when ready for distribution are expected to replace the present darso acreage.

Nearly 25 years ago Roy Schrock, a mail carrier, was driving along the road near Enid, Okla., when he saw a hybrid sorghum plant in a field of kafir. He obtained the heads of this plant from the grower, increased the seed, and later distributed it under the name of Schrock kafir. Like darso, Schrock also has brown seeds but unfortunately it is less drought-resistant. Schrock was grown to some extent in Oklahoma and adjacent States for several years until some growers in Mississippi selected a uniform strain of it and started a new distribution under the name of Sagrain. This time the chief distribution was in Mississippi and nearby States, where the variety is much more promising than in the drier regions. It continues to be popular in the Mississippi Delta, east Texas, and some other sections.

One of the most promising of recent hybrids is the Cheyenne kafir developed by a farmer, Albert Weaver of Bird City, Kans., from a cross between Freed sorghum and some grain sorghum, probably kafir. This variety has white seeds and is extremely early and resistant to drought. Freed sorghum, one of the parents of the above cross, originated from an unknown hybrid and was isolated by J. K. Freed, Scott City, Kans., about 1908. It has maintained its existence under the dry, short-season conditions of extreme western Kansas and eastern Colorado. A dwarf selection from Freed sorghum, made by A. F. Swanson, of the Department of Agriculture, at Hays, Kans., lodges much less than the original type owing to its lesser height. It was distributed in 1926 and has since replaced much of the taller variety.

Wonder kafir is a selection from a field hybrid between kafir and feterita made in 1914 by C. A. Bower, a farmer living near Wallace, Kans. It has appeared to be adapted to conditions favoring a variety slightly earlier than kafir. Further selection of the variety by A. F. Swanson has produced a uniform type that was distributed about 1932.

A variety called Grohoma, that apparently originated from a natural hybrid, achieved considerable notoriety about 5 years ago. Grohoma, according to high-pressure promoters, was produced by grafting a head of kafir on a stalk of sugarcane. The drought resistance and yields of grain, forage, and sirup claimed for Grohoma exceeded the wildest hopes of any farmer dreaming of a bonanza. Experiments and experience failed to substantiate the claims regarding either the origin or the value of Grohoma. It has made some high yields under favorable conditions and is still grown to some extent but is not particularly resistant to drought.

Numerous other grain sorghums developed from field hybrids have enjoyed brief periods of favor without becoming widely grown. Some of them have borne attractive names such as Desert maize, Irish maize, Manko maize, and Tricker sorghum.

SORGO

A few years after Chinese Amber sorgo was introduced, growers began making head selections. The first of the improved strains, called Early Amber, was selected by a farmer, E. Y. Teas of Dunreith, Ind., about 1857. Ten years later another farmer, Seth H. Kenney, Waterville, Minn., selected the Minnesota Amber strain from Early

Amber. Selection in Minnesota Amber at the South Dakota Agricultural Experiment Station by W. A. Wheeler in 1903, and continued selection by A. C. Dillman of the Department of Agriculture, resulted in the distribution about 1915 of Dakota Amber (fig. 9) an extremely early and drought-resistant variety. Selection in Minnesota Amber for sugar content by the Waconia Sorghum Mill, Waconia, Minn., produced Waconia Amber, an excellent variety for sirup, about 1925.

Other selected strains of the Black Amber type of sorgo have been developed, including the Ames Amber by the Iowa Agricultural Experiment Station. Selected natural hybrids of the variety have resulted in the isolation of such varieties as Folger, Colman, and possibly Red Amber. Folger was selected by a farmer of that name, living near Shenandoah, Iowa, during the eighties. Colman, named after Norman J. Colman, formerly Secretary of Agriculture, was selected by A. A. Denton, of the United States Department of Agriculture, at Sterling, Kans., in 1887. It is believed to be the result of a natural hybrid between Kansas Orange and Black Amber sorgos.

The parents of Red Amber are less certain, although it has been suggested that they were Orange and Black Amber. Orange sorgo had been sent to Australia from the United States, and when some of that variety was received back from Australia by the Department of Agriculture about 1903, it contained a mixture that when isolated was named Red Amber.

Orange sorgo, apparently one of Leonard Wray's original introductions, has been subjected to selection on farms so that today several somewhat different strains are available. One, called Kansas Orange, was first grown by the Department in 1881. Seed was secured by G. H. Failyer, chemist of the Kansas Agricultural Experiment Station, in 1883 from I. A. Hedges of St. Louis, Mo. Selection in this variety for yield and sugar content produced the distinct Kansas Orange sorgo that is known today. For 45 years this has been a predominant variety in eastern Kansas.

Waconia Orange, selected and distributed by the Waconia Sorghum Mills, Cedar Rapids, Iowa, is a new, distinct strain of Orange sorgo.

Sumac (Red Top) sorgo is the leading variety grown for forage in Oklahoma, Texas, and New Mexico. It is somewhat too late for western Kansas. In 1916, R. E. Getty of the Department of Agriculture found some plants of Sumac that were shorter and earlier than the common variety on a Kansas farm. He took this material to the Fort Hays branch of the Kansas State Agricultural Experiment Station, where he was employed, and selected a pure early strain that was distributed as Early Sumac in 1922. Both Sumac and Early Sumac produce an abundance of reddish-brown seed, but the seeds unfortunately have that bitter "dark-brown" taste. These varieties have been crossed with white-seeded sorghums, and white-seeded and yellow-seeded types nearly identical with Sumac and Early Sumac except in seed color are being tested. The Kansas and Texas Agricultural Experiment Stations are combining their efforts with those of the Department of Agriculture in developing the more palatable sorghums, although none is yet available for distribution.

An African sorgo called Undendebule was introduced by Peter Collier, while he was chief chemist of the Department of Agriculture, in 1881. It consisted of two types. Later, after Dr. Collier had left the Department, one of the types, isolated by A. A. Denton, was named Collier at the suggestion of Harvey W. Wiley. The Collier

variety has very sweet stalks and a very small loose head. It has recently been crossed with a white-seeded strain from a Sumac hybrid to combine the sweetness of stalk with palatable white seeds.

Other varieties of sorgo developed by the Division of Chemistry during the course of sorghum-sugar experiments include Denton, selected from a field of the Honey variety in 1888, and Rex, or Red X, selected in 1891 from what was claimed to be a natural cross between Sapling and Amber.

Leoti sorgo was found on a farm in Wichita County, Kans., in 1920 by R. E. Getty, of the Department. This variety is very sweet, rather early, and resistant to red spot. Unfortunately it is very susceptible to smut.

Perhaps the outstanding achievement in sorgo improvement is the breeding of Atlas sorgo. A farmer and amateur sorghum breeder, I. N. Farr, of Stockton, Kans., crossed Sourless sorgo with Blackhull kafir. Seed from the first hybrid generation was given to R. E. Getty, who grew the next generation at Hays, Kans., in the United States Department of Agriculture and Kansas Agriculture Experiment Station cooperative sorghum experiments. The material did not appear promising there as most of the plants were too large and too late for dependable growth under the limited moisture and seasonal conditions at Hays.

Selected heads were taken to the Kansas Agricultural Experiment Station at Manhattan by John H. Parker, employed as a plant breeder jointly by the Kansas Station and the Department of Agriculture. Parker continued to select the hybrid plants until he had isolated a uniform type with tall, strong, sweet, juicy stalks, and with palatable white seeds that, if desired, could be threshed and sold as white kafir grain. The variety was named Atlas, after the giant of mythology,

FIGURE 9.—Dakota Amber sorgo, an extremely early drought-resistant variety, selected for the short-season and limited-rainfall section of the northern Great Plains.

FIGURE 10.—Atlas sorgo (left) Kansas Orange sorgo (right), showing the difference in lodging. Atlas sorgo inherited the strong stalks from Blackhull kafir, one of its parents.

because of its strong stalks that resisted lodging much better than other tall sorgos (fig. 10). It was distributed about 1928 and today is the most popular sorgo in eastern Kansas, Missouri, and eastern Nebraska.

Here at last is a dual-purpose crop, producing both sweet forage and palatable grain, that meets with the farmer's approval. The problem of bitter brown seeds found in the other sorgos such as Kansas Orange, Sourless, Sumac, and Black Amber grown in those sections has been eliminated by developing a sorgo having white kafir seed. The strong stalks that resist lodging, also inherited from kafir, have caused it to largely replace the weaker Kansas Orange variety despite the fact that Atlas is slightly inferior in yield. Atlas has the drought-enduring qualities found in other sorghums and because of this has repeatedly surpassed corn as a silage crop during the recent dry years. Many farmers have ceased growing corn for silage, preferring to plant fewer acres with the more dependable Atlas.

BROOMCORN

The first broomcorn grown in the United States was tall and apparently very much like the Evergreen (standard) broomcorn grown in this country and in southern Europe today. Plant selection has resulted in the development of strains differing somewhat in height, length of brush, and time of maturity, but otherwise very similar. The Black Spanish variety of broomcorn differs from all strains of Evergreen in having dark chocolate brown instead of tan or reddish tan chaff.

Strains of the tall or standard type only were grown in the United States from the beginning of commercial broomcorn culture about 1797 until about 1855, when a distinct new dwarf type appeared in Ohio. This is the Whisk Dwarf or Japanese Dwarf variety, about 3 or 4 feet tall, with short fine fibers, that still is grown occasionally. About 8 years later another new dwarf type, the Evergreen Dwarf, appeared in New York. This variety was 4 to 6 feet in height and had fibers about as long as those of the tall (standard) varieties. It is still grown to a considerable extent. The origin of these two dwarf types was a mystery for many years, because they were not grown in Europe and had never been described elsewhere. Crosses between the two dwarf varieties, made by J. B. Sieglinger, produced plants in the first generation like a tall standard variety. This result, together with the study of the hybrids in later generations, indicates that the tall broomcorn on two occasions had lost a single but distinct factor for height by mutation.

Selection of standard broomcorn for quality of brush by farmers and by experimenters at the Ohio Agricultural Experiment Station and elsewhere has increased the uniformity of the fiber and possibly has effected some improvement, without, however, developing any distinct new variety.

In 1910 a farmer in western Oklahoma found a plant representing a new type of dwarf broomcorn. This resulted in the development of the Scarborough (dwarf) variety, which has long smooth fibers mostly free from branches except near the tip. This type of brush commands a premium because it is used for the hurl or outside of the broom that covers the coarser and more irregular brush used in the inside. Scarborough later was purified and distributed by the Department of Agriculture, and it is now the leading variety of dwarf broomcorn.

The stalks of broomcorn are dry and stiff and are not sweet. They are seldom utilized except when livestock are turned in to pasture on the leaves and tops after the brush is harvested. Frequently the heavy growth is cut and burned in order to facilitate plowing. The idea of producing a broomcorn with sweet juicy stalks that would be valuable for forage or sirup has interested several breeders.

In 1903, C. P. Hartley, of the Department of Agriculture, made five different crosses between varieties of broomcorn and sorgo with this in view. Selection from these hybrids continued until 1910, when strains of typical broomcorn having sweet juicy stalks had been isolated. Starting before 1908, a farmer at Monmouth, Ill., isolated two varieties of sweet broomcorn. About 5 years ago another sweet broomcorn was developed by a grower at Mattoon, Ill. Although successful in producing broomcorns with plenty of sweet juice, all three breeders encountered the same difficulty—the brush was not of satisfactory quality or yield, and the new type was less profitable than ordinary broomcorn.

The difficulty is another example of the old saying that "you can't eat your cake and have it too." Carbohydrates manufactured by the leaves of the sorghum plant from carbon dioxide, water, and sunlight must go into the grain, the stalk, or the brush. If part of

the manufactured energy remains in the stalk in the form of sugar, then there must be some sacrifice in the development of seed or fibers or both. Thus a dual-purpose plant has limitations that have not yet been overcome in sweet broomcorn.

At present, broomcorn breeding is largely confined to producing white-seeded varieties and types having brush free from red stain.

A Brief Survey of Sorghum Breeding in Foreign Countries

SORGHUM breeding is being conducted in India, China, Manchuria, South Africa, Australia, Algeria, Morocco, Egypt, Sudan, the Union of Socialist Soviet Republics, and to some extent in other countries or colonies. The chief objective is increased yield under local conditions. This usually involves the selection of either earlier or later strains or better grain or forage types from the varieties grown in the section. Hybridization has been resorted to in parts of India, in Australia, and doubtless elsewhere.

Improved varieties developed in Australia, South Africa, and Sudan might have some value in the United States. Australia grows American varieties of sorgo and broomcorn. The varieties from South Africa and Sudan are adapted to American conditions, and superior varieties from these areas might be superior here. Improved varieties from other countries are unlikely to be of interest for American culture because the types usually grown are too early, too late, or too tall, or are lacking in forage value or seed palatability, or have other characters objectionable to American sorghum growers. Sorghum improvement in China and Manchuria is largely confined to kaoliangs, in India to shallu and durra, and to durra also in the Mediterranean region.

Plant breeders in the Union of South Africa have developed a kafir resistant to witchweed, a parasitic flowering plant, behaving like dodder and mistletoe, that attaches itself to a stalk of sorghum or corn and lives on the juices of the host plant.

India leads in sorghum breeding in foreign countries, both hybridization and selection being applied. The experiments have included extensive genetic studies, determinations of the relation of certain plant characters to yield, and studies of flowering habits and plant development. Large heads and stalks have been shown to be correlated with high yield per plant. Most of the sorghum breeding in India has been done in the Madras and Bombay Presidencies. The contributions to sorghum breeding at the Agricultural Research Station at Coimbatore in Madras, under the leadership of G. N. Rangaswami Ayyangar, millet specialist, are the most extensive and comprehensive. The first sorghum-sugarcane crosses were made at that station.

Advances Made in the Fundamental Knowledge of Inheritance in Sorghums

THE study of inheritance in sorghums is still in its infancy. It began many years after natural crosses in sorghums had been utilized in sorghum improvement. Apparently the first recorded tangible improvement from a natural hybrid in sorghum was the selection of Colman sorgo in 1887 by A. A. Denton. No data were presented regarding the inheritance of plant characters in that cross.

Insofar as can be ascertained, the first planned artificial sorghum hybrids made in this country or elsewhere were those of C. P. Hartley, of the Department of Agriculture, made at Washington, D. C., in 1903. Mr. Hartley produced five hybrid combinations between broomcorn and sorgo involving three varieties of broomcorn and four of sorgo. The F_1 plants and the few F_2 plants were described, but the hereditary factors involved were not determined. The F_1 plants of the cross between Collier sorgo, with plants 10 feet tall, and Dwarf broomcorn, with plants 5 feet tall, attained a height of 14 feet. This probably represents the first positive genetic demonstration of complementary height factors in sorghum, although the characteristic tallness of sorghum hybrids was observed by Harvey W. Wiley in 1891, and by farmers and others nearly 30 years earlier.

Numerical genetic segregations in sorghum hybrids were first reported by Graham in India in 1916. The first artificial grain sorghum hybrids in the United States were made by H. N. Vinall and A. B. Cron, of the Department of Agriculture, in a greenhouse at Washington, D. C., in 1914. These men at that time succeeded in producing 14 hybrid combinations involving varieties of grain sorghum, sorgo, and Johnson grass. The inheritance of certain characters in some of these crosses was reported in 1921. The two papers, one by Graham and one by Vinall and Cron, thus mark the beginning of sorghum-genetics literature.

A list of simple hereditary character factors in sorghum is presented in table 1. This is not quite complete, but it includes the results reported to or obtained by the writer in addition to those found in the literature. Those most active in the investigation of sorghum inheritance include R. E. Karper, A. B. Conner, J. R. Quinby, and others of the Texas Agricultural Experiment Station; J. C. Stephens, J. B. Sieglinger, and others of the Department of Agriculture; and G. N. R. Ayyangar and his associates, located at the Agricultural Research Institute, Coimbatore, Madras, India.

Many of the unit characters studied were abnormalities in the development of chlorophyll. Some of these and other abnormalities have developed naturally, but the X-ray treatment of seeds has produced a considerable number of the defective types.

Color differences have been another fruitful source of inheritance studies. Not less than seven distinct factors operate to determine the color of sorghum seed. These and probably others in various combinations are responsible for the variety of colors found. One useful peculiarity is that the basic color factor in the pericarp or seed coat also

is present in the leaves, boots, and flower parts. By examining the stigmas and anthers, it is thus possible to determine before the seed is formed whether a plant or variety will produce seeds with a colored red or yellow pericarp. After harvest the color of the stubble also tells the story. Two other useful correlations are the color of the leaf midrib, which reveals the dryness or juiciness of the stalk, and chalkiness of the seed coat, which is evidence that the variety probably is susceptible to seed rots and that the grower may have difficulty in securing stands.

A series of four distinct height classes has been found in broomcorn, and it appears that the same or a similar set of factors produces parallel height groups in milo, kafir, feterita, and probably kaoliang. The double dwarf height has been found to be extremely useful in milo, but it is of questionable value in kafir and feterita and apparently is a worthless freak in broomcorn because the brush is too short for the usual industrial use.

When two varieties of dwarf broomcorn, Evergreen Dwarf and Japanese Dwarf, representing two different dwarf height classes, are crossed, the first-generation plants are tall like standard broomcorn. In the second generation the population breaks up into a definite ratio (9 : 3 : 3 : 1) of plants of the heights typical of standard, Evergreen Dwarf, Japanese Dwarf, and double dwarf broomcorn. The number of joints in the stalk is the same in all classes but the joints differ in length. When Dwarf Yellow milo is crossed with Dwarf kafir the first generation again is much taller than either parent, and in the second generation tall and different dwarf heights are obtained. The proportions are similar to those mentioned for broomcorn crosses but are not so readily recognized because of other growth-factor differences. Recombination of the complementary height or internode-length factors thus accounts in part for the manifestation considered as hybrid vigor in sorghums. In crosses between different groups of sorghum, namely, milo and kafir, there are complementary factors, not yet fully analyzed, that increase the number of leaves or joints on the hybrid sorghum stalk. Associated with an increase in leaf number are thicker leaves, thicker stalks, later maturity, and greater vigor. Hybrid vigor in sorghums as ordinarily observed, therefore, is largely explained by the fact that the internodes are longer, and there are more nodes. In addition, there are other undefined growth factors that sometimes produce increased yields in crosses even between closely related varieties.

The factors that are apparently inherited independently are listed in table 3, and the four determined linkage groups are shown in table 2. Not less than 5 of the total of 10 linkage groups in sorghum are necessary to account for the independent factors shown in table 3.

A list of the investigators now carrying on most of the sorghum breeding in the United States and a few of the most active workers abroad appears in the appendix.

The knowledge thus far acquired from the studies of the inheritance of sorghum characters has greatly simplified both the planning and execution of breeding new, superior varieties. It has been shown that in the 80 years since sorghum improvement began in this country, plant breeders have developed varieties suitable for diverse environments, conditions, and uses. Likewise in 20 years of investigation these breeders have solved many of the mysteries of sorghum inheritance.

Appendix

TABLE 1.—*Character inheritance in sorghum*

Dominant-recessive characters	Symbols	Ratio	Authority and date published, observed, or reported
Seedling:			
Red coleoptile, green	*Rr*	3:1	Reed (1930), Karper and Conner (1930), Ayyangar (1930).
Normal chlorophyll, white	W_1w_1 to W_4w_4 (inclusive).	3:1	Karper and Conner (1930).
Do	W_5w_5 to $W_{12}w_{12}$ (inclusive).	3:1	Quinby and Karper (1934).
Normal chlorophyll, virescent	V_1v_1 and V_2v_2	3:1	Karper and Conner (1930).
Do	V_3v_3 to V_8v_8 (inclusive).	3:1	Quinby and Karper (1934).
Normal chlorophyll, yellow	Y_1y_1 to Y_4y_4 (inclusive).	3:1	Karper and Conner (1930).
Do	Y_5y_5 and Y_6y_6	3:1	Quinby and Karper (1934).
Normal chlorophyll, lethal white		3:1	Ayyangar and Ayyar (1932).
Normal chlorophyll, lethal virescent white.		3:1	Do.
Normal chlorophyll, lethal pale		3:1	Do.
Normal chlorophyll, lingering lethal pale.		3:1	Do.
Normal chlorophyll, surviving pale.		3:1	Do.
Normal chlorophyll, pale green	Pg_1pg_1 to Pg_3pg_3 (inclusive).	3:1	Quinby and Karper (1933).
Stalk:			
Tall kafir, normal height	*Tt*	3:1	Karper (1932).
Normal kafir, double dwarf height		3:1	Sieglinger (1933).
Standard milo, dwarf height	D_1d_1	3:1	Karper (1930).
Dwarf milo, double dwarf height	D_2d_2	3:1	Do.
Standard broomcorn, western dwarf height.	*Aa*	3:1	Sieglinger (1932).
Standard broomcorn, Japanese dwarf height.	*Dd*	3:1	Do.
Tall shallu, dwarf height		3:1	Ayyangar (1934).
Short early durra, tall late		3:1	Do.
Normal height kafir, midget	*Mm*	3:1	Quinby and Karper.
Normal thickness kafir, tenuous		3:1	Sieglinger (1929).
Dry stalk (white leaf midrib), juicy stalk (gray midrib).	*Dd*	3:1	Hilson (1916), Swanson and Parker (1931), Stephens and Quinby (1930).
Purple nodal band, green		3:1	Ayyangar (1934).
Late, early maturity	*Ee*	3:1	Stephens and Quinby (1931), Karper (1932).
Plant colors:			
Basic red or yellow leaves, stigmas, anthers, and pericarp; absence of color.	*Rr*	3:1	Graham (1916), Sieglinger (1933).
Normal green, red leaves and stems.	*Crcr*	3:1	Stephens and Quinby (1931).
Normal green, yellow leaves and stems.	Cy_1cy_1	3:1	Stephens and Quinby (1932).
Do	Cy_2cy_2	3:1	Stephens and Quinby (1933).
Normal green, golden leaves and stems.	*Cgcg*	3:1	Stephens and Quinby (1932).
Purple spots, brown	*Pp*	3:1	Ayyangar (1933), Swanson and Martin (1932).
Reddish-purple spots, blackish purple.	*Qq*		Ayyangar.
Leaf:			
White midrib, gray midrib	*Dd*	3:1	Hilson (1916), Swanson and Parker (1931).
Normal, yellow	Y_1y_1	3:1	Quinby and Karper (1934).
Normal, fired	F_1f_1	3:1	Do.
Normal, zebra	*Zz*	3:1	Do.
Yellow midrib, nonyellow			Martin (1931).
Panicle:			
Short branches, long branches		3:1	Karper (1931).
Short rachis, long rachis		3:1	Do.
Few nodes, many nodes		3:1	Do.
Loose panicle, compact		3:1	Ramanthan (1924), Parker (1927), Ayyangar (1934).
Loose conicle, compact spindle		3:1	Ayyangar (1934).
Normal flowered, multiflorous	*Mf mf*	3:1	Karper (1932).
Red pedicelled spikelets, nonred		3:1	Ramanthan (1924).

TABLE 1.—*Character inheritance in sorghum*—Continued

Dominant-recessive characters	Symbols	Ratio	Authority and date published, observed, or reported
Glume:			
Wrinkled, smooth		3:1	Ramanthan (1924).
Broad, narrow		3:1	Vinall and Cron (1921), Ayyangar (1934).
Pubescent, glabrous (also pubescence on rachis and node).		3:1	Ramanthan (1924).
Black, straw color	*Gs gs*	3:1	Stephens and Quinby (1931).
Black, red	*Gr gr*	3:1	Do.
Red, black	*Gb gb*	3:1	Do.
Red or black, brown	*Pp*	3:1	Ayyangar et al. (1933), Stephens and Quinby (1934).
Red tip, nonred		3:1	Ramanthan (1924).
Awn:			
Awnless, awned	*Aa*	3:1	Vinall and Cron (1921), Ramanthan (1924), Sieglinger et al. (1934), Ayyangar (1934).
Awnless, tip awn	*A* a_t	3:1	Sieglinger et al. (1934).
Awned, tip awn	*a* a_t	1:2:1	Sieglinger et al. (1934), Ayyangar (1934).
Anther:			
Normal, antherless	*Alal*	3:1	Stephens, Karper, and Quinby (1933).
Purple base, nonpurple		3:1	Ayyangar (1934).
Brick red-tan (when dried), tan	*Rr*	3:1	Graham (1916), Sieglinger (1933).
Stigma: Yellow, white	*Rr*	3:1	Do.
Seed:			
Brown nucellar layer, absent	*Bb*	3:1	Sieglinger (1923), Swanson (1929).
Spreader or thin mesocarp, thick mesocarp.	*Ss*	3:1	Do.
Colored pericarp, colorless	*Rr* or *Yy*	3:1	Graham (1916), Vinall and Cron (1921, Conner and Karper (1931), Sieglinger (1924) (1933), Swanson (1929).
Color modifier, absent	*Yy* or *Rr*	3:1	Graham (1916), Ayyangar et al. (1933).
Whole color, colored base	*Ww*	3:1	Ayyangar et al. (1933).
Intensified color (red), pink	*Ii*	3:1	Ayyangar (1934).
Pearly endosperm, chalky	*Zz*	3:1	Do.
Starchy endosperm, waxy	*Wx wx*	3:1	Karper (1933).
Starchy, sugary	*Su su*	3:1	Karper (1933), Ayyangar (1934).
Disease resistance:			
Smut susceptibility resistance	*Kk*	3:1	Reed (1930), Swanson and Parker (1931).
Smut resistence, susceptibility		3:1	Reed (1930).
Red-spot susceptibility, resistance		3:1	Swanson and Martin (1932).
Root-rot susceptibility, resistance		3:1	Bowman et al. (1934).

TABLE 2.—*Sorghum factors linked*

Characters	Symbols	Percentage crossing over	Authority and date reported
Group 1:			
Nucellar layer and glume color	*B, gb*	4.5	Stephens and Quinby (1931).
Do.	*b, Gr*	25	Stephens and Quinby (1929).
Do.	*b, Gb*	21	Do.
Group 2:			
Red coleoptile and midrib color	*R, m*	21.5	Stephens and Quinby (1930).
White seedlings and red coleoptile	W_3, *R*	41.34	Karper (1930).
Group 3:			
Yellow seedlings and waxy endosperm	Y_2, *WX*	26.5	Do.
Group 4:			
Yellow leaves and stems and pericarp color.	*Cy, Pr*	13	Stephens and Quinby (1933).

TABLE 3.—*Distinct sorghum factors, probably inherited independently*

Characters	Symbols	Ratio	Authority and date published, observed, or reported
White seedlings and yellow seedlings	W_1, Y_3	9:3:4	Karper (1933).
Do	W_2, Y_1	9:7	Do.
Do	W_2, Y_3	9:7	Do.
White seedlings and red coleoptile	W_1, R	9:7	Karper (1932).
Do	W_2, R	9:7	Do.
White seedlings and waxy endosperm	W_1, Wx	9:3:3:1	Karper (1933).
White seedlings and sugary endosperm.	W_1, su	9:3:3:1	Karper (1934).
Do	W_2, su	9:3:3:1	Do.
Virescent seedlings and waxy endosperm.	V_1, Wx	9:3:3:1	Karper (1933).
Virescent seedlings and sugary endosperm.	V_1, su	9:3:3:1	Karper (1934).
Virescent seedlings and waxy endosperm.	V_2, Wx	9:3:3:1	Karper (1933).
Virescent seedlings and yellow seedlings.	V_2, Y_3	9:6:1	Do.
Yellow seedlings and yellow seedlings	Y_1, Y_2	9:7	Karper (1932).
Do	Y_2, Y_3	9:7	Do.
Yellow seedlings and red coleoptile	Y_1, R	9:3:3:1	Do.
Do	Y_2, R	9:3:3:1	Do.
Do	Y_3, R	9:3:3:1	Do.
Yellow seedlings and waxy endosperm	Y_1, Wx	9:3:3:1	Karper (1933).
Do	Y_3, Wx	9:3:3:1	Do.
Waxy endosperm and red coleoptile	Wx R	9:3:3:1	Do.
Waxy endosperm and sugary endosperm.	Wx,, su	9:3:3:1	Karper (1934).
Standard height and double dwarf height.	d_1, d_2	9:3:3:1	Do.
Awns and pericarp color	A, Pr	9:3:3:1	Stephens and Quinby (1931).
Spreader and pericarp color	S, Pr	12:3:1	Stephens and Quinby (1933).
Glume color (dominant black) and pericarp color.	Gr. Pr		Stephens and Quinby (1929).
Glume color (dominant red) and pericarp color.	Gb, Pr		Stephens and Quinby (1933).
Spreader and glume color (dominant black).	S, gr		Stephens and Quinby (1929).
Spreader and glume color (dominant red).	S, gb		Stephens and Quinby (1933).
Awns and glume color (dominant black.	a, gr	9:3:3:1	Do.
Awns and glume color (black or straw)	a, gs	9:3:3:1	Stephens and Quinby (1931).
Awns and glume color (dominant red)	g, gb	9:3:3:1	Stephens and Quinby (1933).
Yellow leaves and stems and glume color (dominant red).	Cy, Gb		Do.
Awns and spreader	a, S	9:3:3:1	Stephens and Quinby (1930).
Awns and nucellar layer	a, b		Stephens and Quinby (1930), Sieglinger (1934).
Nucellar layer and pericarp color	b, Pr	9:3:3:1	Stephens and Quinby (1931), Sieglinger (1934), Swanson (1928).
Nucellar layer and spreader	b, S		Stephens and Quinby (1930), Sieglinger (1924).
Red coleoptile and nucellar layer	R, b		Stephens and Quinby (1930).
Red coleoptile and spreader	R, s	9:3:3:1	Stephens and Quinby (1932).
Red coleoptile and awns	R, a	9:3:3:1	Stephens and Quinby (1930).
Glume color (dominant black) and midrib color.	gr, m	9:3:3:1	Stephens and Quinby (1933).
Glume color (black or straw) and midrib color.	gs, m	9:3:3:1	Stephens and Quinby (1931).
Glume color (dominant red) and midrib color.	gb, m	9:3:3:1	Stephens and Quinby (1933).
Pericarp color and midrib color	Pr, m	9:3:3:1	Do.
Yellow leaves and stems and midrib color.	Cy, m		Do.
Red leaves and stems and midrib color	Cr, m	9:3:3:1	Stephens and Quinby (1932).
Midrib color and awns	m, a		Stephens and Quinby (1930).
Spreader and midrib color	S, m	9:3:3:1	Stephens and Quinby (1931).
Midrib color and nucellar layer	M, b	9:3:3:1	Stephens and Quinby (1930).
Yellow leaves and stems and nucellar layer.	Cy, b		Stephens and Quinby (1933).
Red leaves and stems and nucellar layer.	Cr, b	9:3:3:1	Stephens and Quinby (1932).
Golden leaves and nucellar layer	Cg, b		Stephens and Quinby (1931).
Red leaves and stems and awns	Cr, a	9:3:3:1	Do.
Red leaves and stems and spreader	Cr, S	9:3:3:1	Stephens and Quinby (1932).
Red leaves and stems and glume color (dominant black).	Cr, Gr	9:3:3:1	Do.
Golden leaves and awns	Cg, a		Stephens and Quinby (1933).
Golden leaves and glume color (dominant black).	Cg, Gr		Do.
Golden leaves and pericarp color	Cg, Pr		Do.
Dry stalk and smut resistance	m (D) k	9:3:3:1	Swanson and Parker (1931).
Dwarf and whisk dwarf height in broomcorn.	A, D	9:3:3:1	Sieglinger (1932).

Investigators Now Carrying on Most of the Sorghum Breeding in the United States

United States Department of Agriculture:

Bureau of Plant Industry, Division of Cereal Crops and Diseases:
J. H. Martin, Washington, D. C.
J. B. Sieglinger, Woodward, Okla.
J. C. Stephens, Chillicothe, Tex.
A. F. Swanson, Hays, Kans.
J. H. Parker, Manhattan, Kans.
R. O. Snelling, Lawton, Okla.
B. F. Barnes, Dalhart, Tex.
D. R. Burnham, Tucumcari, N. Mex.
J. J. Curtis and J. F. Brandon, Akron, Colo.

Kansas State Agricultural Experiment Station:
J. H. Parker, Manhattan.
F. A. Wagner, Garden City.
T. B. Stinson, Tribune.
E. H. Coles, Colby.

Oklahoma Agricultural Experiment Station:
W. B. Gernert and J. C. Ireland, Stillwater.
H. A. Daniel, Goodwell.

Texas Agricultural Experiment Station:
R. E. Karper, College Station.
J. R. Quinby, Chillicothe.
D. L. Jones and Frank Gaines, Lubbock.

Arizona Agricultural Experiment Station:
I. A. Briggs and A. T. Bartel, Tucson.
C. J. Wood, Mesa.

California Agricultural Experiment Station:
G. W. Hendry, Davis.

Arkansas Agricultural Experiment Station:
C. K. McClelland, Fayetteville.

South Dakota Agricultural Experiment Station:
C. J. Franzke, Brookings.

Illinois Agricultural Experiment Station:
C. M. Woodworth, Urbana.

Prominent Sorghum Breeders in Foreign Countries [3]

Australia:

Department of Agriculture, Sydney, New South Wales:
W. H. Darraugh.

India:

Madras Agricultural Department, Research Institute, Coimbatore, Madras:
G. N. Rangaswami Ayyangar.

Bombay Department of Agriculture, Bombay:
M. L. Patel.

Bombay Department of Agriculture in Sind, Experimental Station, Sakrand:
K. I. Thadani.

Union of South Africa:

Union Department of Agriculture, Pretoria:
M. G. Stahl, F. H. Bosman.

School of Agriculture, Potchefstroom:
J. J. du Toit.

School of Agriculture, Glen, O. F. S.:
J. P. F. Sellschop.

[3] This does not include experimenters in China, Manchuria, north Africa, Union of Socialist Soviet Republics, and parts of India who are doing considerable selection in domestic or introduced sorghums.

TABLE 4.—*Improved varieties of sorghum developed by the U. S. Department of Agriculture and State agricultural experiment stations*

Variety and organization	When introduced, selected, or crossed	When distributed (approximate year)	By whom produced	Breeding method used	In what way superior	Parent material
U. S. Department of Agriculture:						
Colman sorgo	1887	1891	A. A. Denton	Selection	Sweeter stalk	Natural hybrid.
Collier sorgo	1888	1891	do	do	do	Mixed introduction.
Dwarf Yellow milo	1906	1907	C. R. Ball, A. H. Leidigh	do	High yield, drought resistance, short stalk.	Dwarf mutation of Standard Yellow milo grown by a farmer.
Feterita	1906	1910	A. B. Conner, H. N. Vinall	Introduction and purification	Early, drought resistant, smut resistant.	Introduction from Sudan.
Dawn kafir	1907	1911	C. R. Ball, A. H. Leidigh	Selection of natural hybrid	Short stalks, earliness, drought resistance.	Blackhull kafir.
Sunrise kafir	1907	1911	do	do	Earliness, drought resistance, palatable forage.	Do.
Beaver milo	1919	1928	J. B. Sieglinger	Hybridization and backcross to milo parent.	Erect heads and short stalks, suitable for combining.	Dwarf Yellow milo-Blackhull kafir hybrid.
Wheatland milo	1919	1931	do	Hybridization	do	Do.
Sooner milo	1924	1930	do	do	Early	Early white milo × Dwarf Yellow milo.
Day milo	1924	(1)	do	do	Early, short stalk for combining.	Do.
Pygmy milo	1924	(1)	do	do	do	Do.
Texas Agricultural Experiment Station:						
Dwarf Yellow milo [2]	1906	1907	A. B. Conner	Selection	High yield, drought resistance, short stalk.	Dwarf mutation of Standard Yellow milo grown by a farmer.
Dwarf Yellow milo 670		1923	R. E. Karper, D. L. Jones	Selection and inbreeding	Uniformity, yield	Dwarf Yellow milo.
Dwarf hegari [2]	1910	1914	A. B. Conner, H. N. Vinall	Selection	Yield and quality of forage	Selected from hegari introduced from Sudan in 1908.
Spur feterita	1914	1919	R. E. Dickson	do	High yield, greater leafiness, immunity to smut.	Feterita introduction.
Dwarf feterita	1914	1920	do	do	Short stalks	Do.
Chiltex [2]	1914	1923	H. N. Vinall, A. B. Cron	Hybridization	Drought resistance	Feterita × Blackhull kafir.

Premo [2]	1914	1923	do	do	High yield	Do.
Blackhull kafir 153	1916	1920	R. E. Karper, A. B. Conner	Selection and inbreeding	Yield, uniformity	Blackhull kafir.
Texas Blackhull kafir	1916	1924	R. E. Karper	do	Earliness, drought resistance	Do.
Ajax [2]	1923	1930	J. R. Quinby, J. C. Stephens	Hybridization	Short stalk, yield	Premo × Spur feterita.
Early Yellow milo	1926	1932	D. L. Jones, J. R. Quinby	do	Earliness	Dwarf Yellow milo × Early White milo.
Oklahoma Agricultural Experiment Station:						
Darso	1912	1914	O. O. Churchhill, A. H. Wright.	Purification and selection	Drought resistance, chinch bug resistance, yield.	Selected natural hybrid.
White darso	1925		C. D. Haston	Selection	Palatable seed	Natural hybrid.
Kansas Agricultural Experiment Station:						
Kansas Orange	1883	1890	G. H. Failyer, J. T. Willard	do	High yield, high sugar content	Unselected variety.
Blackhull kafir	1895	1898	C. C. Georgeson	do	High yield	Do.
Pink kafir [2]	1908	1916	A. D. Colliver, C. C. Cunningham.	do	Earliness, forage yield	Imported kafir.
Early Sumac sorgo [2]	1916	1922	R. E. Getty	do	Earliness, drought resistance	Mixed lot of partly selected Sumac.
Atlas sorgo [2]	1923	1928	I. N. Farr, J. H. Parker	Hybridization	Strong stalks, palatable seed	Sourless sorgo × Blackhull kafir.
Greeley [2]	1918	1932	C. C. Cunningham, T. B. Stinson, J. H. Parker.	do	Drought resistance, early maturity.	Pink kafir × Freed sorghum.
Dwarf Freed [2]	1921	1926	A. F. Swanson			
Kalo [2]	1921	1933	do	Hybridization	Earliness, low-temperature resistance.	Pink kafir × Dwarf Yellow milo.
Early kalo [2]	1930	1934	do	Selection	Extreme earliness	Kalo.
Club kafir [2]	1919	(1)	do	do	High yield	Dawn kafir.
Leoti sorgo	1920	(1)	R. E. Getty	do	Sweet stalk, resistance to red spot.	Mixed variety.
Colorado Agricultural Experiment Station:						
Elton [2]	1920	1928	J. F. Brandon	do	Early maturity	Natural hybrid.
Highland [2]	1920	(1)	F. A. Coffman, J. F. Brandon	do	do	Do.
Colorado Sumac [2]	1925	(1)	J. F. Brandon, J. J. Curtis	do	do	Do.

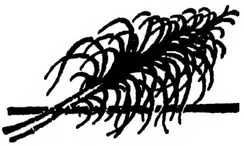
See footnotes at end of table.

TABLE 4.—*Improved varieties of sorghum developed by the U. S. Department of Agriculture and State agricultural experiment stations*—Con.

Variety and organization	When introduced, selected, or crossed	When distributed (approximate year)	By whom produced	Breeding method used	In what way superior	Parent material
Arizona Agricultural Experiment Station:						
Dwarf hegari	1920	1922	C. J. Wood	Selection	Uniformity, high yield	Dwarf hegari.
California Agricultural Experiment Station:						
Heileman milo		1921	B. A. Madson, G. W. Hendry	do	Uniformity	Mixed Dwarf Yellow milo.
Double Dwarf milo	1918	1924	G. W. Hendry, J. P. Conrad	do	do	Do.
Hobay	1930	(1)	G. W. Hendry	Hybridization	Dwarfness	Dwarf White durra × Chimbay.
South Dakota Agricultural Experiment Station:						
Altamont kaoliang [2]	1909	1911	M. Champlin	Selection	Early	Manchu Brown kaoliang.
Dakota Amber sorgo [2]	1903	1915	A. C. Dillman, W. A. Wheeler	do	do	Minnesota Amber sorgo.
Louisiana Agricultural Experiment Station:						
Shallu	1890	1892	W. C. Stubbs	Introduction	Resistance to red spot, high protein content of seed.	Introduction from India.

[1] Not distributed officially.
[2] Developed in cooperation with the U. S. Department of Agriculture.

Sugarcane: Its Origin and Improvement



By E. W. Brandes, Principal Pathologist in Charge, and G. B. Sartoris, senior pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry

ONLY a few generations ago, when subsistence farming in the United States was more than a name, our forefathers made rare periodical trips to town for supplies. A bag of sugar from the West Indies was one of the few purchases for which a cash outlay was required. The frontiersman spent a considerable proportion of his limited income for this luxury, which was used for preserving fruits and to supplement the "long sweetenin' "—the sirups of maple or sorgo produced by himself or his neighbors. His bread and meat, dairy products, vegetables and fruits, even his homespun clothing, soap, candles, and often shoes were products of his own industry and that of his family.

For the majority of American families, sugar remained a large item in the budget down to very recent times. Today, even with the manifold increase in per-capita consumption, the cost is relatively insignificant. And while sugar has become a prime necessity and is recognized as a strategic military requirement in wartime, furnishing about 13 percent of the total energy we obtain from foods, modern methods of refining and handling have made it a standard for purity among foods. Sugar manufacturing is one of the most efficient modern industries, and unquestionably the most efficient agricultural industry. In quality, the product is equaled by very few others, and in quantity of raw material utilized the sugar industry is comparable to the heavy industries. A good modern plantation will harvest, transport, mill, and recover the sugar from 4,000 tons of cane every 24 hours.

The purity and cheapness of sugar is the result of concentration on problems of production and manufacture by hundreds of technologists, biologists, chemists, producers, and handlers in the industry. To consolidate the gains made and provide stabilized and adequate

supplies at reasonable prices, with due regard for a decent living for the sugar farmer, is a problem that continues to challenge the ingenuity and resources of technologists. The most important part of the task at the present time devolves upon the plant breeder.

The Significance of Plant Breeding to the Sugar Industry

IN LOUISIANA and other Southern States, further economies in production are quite possible by improvement of the sugarcane plant. Among species and varieties now available there is great variation in respect to the characters important in determining the economic usefulness of the plant. To mention only a few:

The amount of sugar and the relative proportion of sugar and other solids in the juice vary in the different kinds of cane, and the time required to reach the degree of maturity suitable for processing also varies. The relative maturity of different portions of the stalk varies, and there are great contrasts in the specific gravity, diameter, and length of stalk. Habit of growth is important, and this, together with stooling ability, offers a great range for selection. Variation is found in the response to soils, soil amendments, weather conditions, and other features of the environment. Some varieties resist deterioration better than others after a freeze or when windrowed.

Poor or gappy stands of plant cane and unsatisfactory stands of succeeding crops—the ratoons or stubble crops obtained without replanting—can usually be traced to certain specific diseases. Among the different kinds of cane there is great variation in response to infection and sometimes there is complete immunity to a disease. Among all the morphological and physiological differences observed in the different varieties of cane, the variation in response to diseases stands next in importance to variation in absolute quantity of sugar in determining the economic worth of the plant. Lack of resistance to mosaic in varieties formerly grown in Louisiana brought the industry to the brink of ruin a dozen years ago. Securing varieties resistant to the disease, after careful study and search, brought about the sensational recovery of the industry after it was forsaken as a business risk by almost all financing institutions.

This virus disease was introduced, probably about 1914, in stem cuttings of cane varieties originally from the Orient or South Pacific islands, where it was first described as injurious to the plant in the latter part of the past century. In 1919–20 workers in the Bureau of Plant Industry proved the infectious nature of mosaic and its transmission by insects and demonstrated the wide range of tolerance by different cane varieties and species. Conditions in Louisiana were favorable for rapid spread of the disease through the agency of the insect carrier, *Aphis maidis*, and production of sugar fell from an average of over 200,000 tons a year to a low of 47,000 tons, which was reached in 1926. It is estimated that losses to the sugar and sirup industries of the South due to mosaic amounted to $100,000,000.

Attention to selection of resistant varieties suitable for commercial culture and breeding for intensification of their qualities of resistance

had begun several years before 1926 at the United States Sugar Plant Field Station near Canal Point, Fla. A world-wide search for resistant parent material marked the beginning of these efforts. Results have exceeded expectations; the sugar industry in Louisiana and the sugar and sirup industries of the other Southern States are not merely restored to former levels of production, but yields of sugar per acre are higher and are obtained at less cost than before the mosaic epidemic.

The stimulating effect of the project extended to other sugar-producing countries where mosaic was a factor, notably Puerto Rico where attention to disease-resistant varieties was emphasized by the early investigations there of workers in the Bureau of Plant Industry and later by other agencies. With continuation of breeding the forecast is for a gradual shift to better varieties for many years to come.

The plant breeder has demonstrated that he can meet the challenge of diseases and, as in this case, turn it to advantage.

WHAT IS SUGARCANE?

As the dictionary definition of sugarcane, "A tall stout perennial grass (*Saccharum officinarum*) of tropical regions, rich in sugar," is of value only for the most general usage, it would be well to delimit the term as used in this article and to point out a few of the misconceptions about sugarcane and related plants commonly met with in the United States.

Cultivated sugarcane, grown commercially in the Southern States, comprises many hybrid varieties that have resulted from natural or artificially controlled crosses of a number of species of *Saccharum*, including the species given in the dictionary, *S. officinarum*. Some of these species are not strictly tropical but range far into the North Temperate Zone. Moreover, in contrast with *S. officinarum*, they are not "stout" and are not "rich in sugar," yet owing to the lack of definitive common names in the English language they must all be admitted under the inclusive common name of sugarcane.[1]

In addition to the forms cultivated in this country, there are others representing crosses between genera which, for the present at least, must also be included under the name "sugarcane." These are the forms known in Malaya as Tebu glongong and Tebu trubu and several similar ones recently collected (*4*)[2] in New Guinea, all of which appear to be natural crosses between *Saccharum* and *Erianthus*. The stems are rich in starch rather than sugar and the plants are utilized by the natives for their edible flowers.

Until special common names come into use, it will be convenient to refer to all wild or cultivated plants classified botanically under the genus *Saccharum*, or hybrids having an admixture of such plants, as sugarcane, but with modifying adjectives when necessary for clearness.

In some parts of the United States a related annual plant, sorgo or sweet sorghum—also recently crossed with sugarcane—belonging to the genus *Sorghum* is often erroneously called sugarcane, sometimes with the prefix "seeded" to indicate that it is propagated by

[1] In the Javanese language the common wild sugarcane, *S. spontaneum*, is distinguished from others by the term glagah, and this word has been adopted by the Netherlanders resident in Java.

[2] Italic figures in parentheses refer to literature cited, pp. 610-611.

seeds instead of stem cuttings, as is the case with true sugarcane. Loosely used expressions such as "canebrake" have also served to add confusion to terminology in this country. A canebrake is a wild growth of reeds or canes, usually of *Arundinaria gigantea* or *Panicum hemitomon*. As no wild sugarcane is established here, it is obviously improper to use the expression in referring to sugarcane, but it is often used in a way that suggests that canebrakes are made up of sugarcane or that cultivated fields of sugarcane are canebrakes, neither of which is correct.

Typical flowers of the sugarcane are illustrated in figures 1 and 2.

PROBABLE ANCESTORS OF CULTIVATED SUGARCANE AND THEIR GEOGRAPHICAL DISTRIBUTION

The cultivated sugarcanes are probably derived from wild species of *Saccharum* (*S. spontaneum*, *S. robustum*, and unknown or extinct species), but as they sometimes appear to hybridize with other genera in nature, the latter may not be entirely excluded from consideration in tracing the origin of sugarcane. Assuming immediate descent from existing wild forms would be premature, for there is no doubt that most if not all present varieties of sugarcane are the result of extensive hybridization, the history of which has not been traced and therefore cannot be used as a basis upon which to determine questions of derivation with accuracy.[3]

The wild sugarcanes, *S. spontaneum* and *S. robustum*, are, so far as known, restricted to southern Asia and the chains of islands in the Indian and Pacific Oceans adjacent to southeastern Asia. The range of *S. spontaneum* seems to be much greater than that of *S. robustum*, extending from Turcomania and Afghanistan on the west to Melanesia and Taiwan on the east. Wild sugarcane of that species has been reported even from some of the small southern Pacific islands,[4] but great antiquity of the species at either extreme of the present range is not necessarily assumed.

Sugarcane of economic usefulness has been transported by man probably for some thousands of years. When established in places specially favorable for natural reproduction by seeds, the wild forms capable of maintaining themselves in competition with other wild vegetation would be segregated from some of the hybrid cultivated forms, also transported by man, and could maintain themselves as wild plants. Doubtless this accounts for the presence of *S. spontaneum* in Tahiti, reported by John Reinhold Forster when he accompanied Capt. James Cook in 1773.

The Polynesians made many long voyages after they become skillful navigators and carried food plants, including sugarcane, to most, but not all, of the Pacific islands. It is likely that some of the long voyages were involuntary, caused by sudden storms during coast-

[3] Available morphological and cytological evidence of such derivation is discussed later in this article under the genetics of sugarcane.

[4] Explorations in these islands and Australia for the U. S. Department of Agriculture in 1935 by one of the writers resulted in the discovery of wild-growing sugarcane in Tahiti and Raiatea of the Society Islands, Efate of the New Hebrides, Viti Levu of the Fiji Islands, and New Caledonia. The sugarcane from Efate has been provisionally determined to be a variety of *S. robustum*, but the others, not yet determined, may be *S. spontaneum*. The occurrence of the latter species in Australia, reported by K. Domin in 1910, could not be confirmed, although an assiduous search was made along Harvey's Creek in northeastern Queensland, the place indicated by Domin. A. H. Bell of the Queensland Bureau of Sugar Experiment Stations and other members of the staff have also sought repeatedly for indigenous sugarcane in that region but without success. Strangely enough, it seems that in spite of the proximity of Australia to New Guinea and other natural habitats, wild cane is not found under natural conditions on that continent.

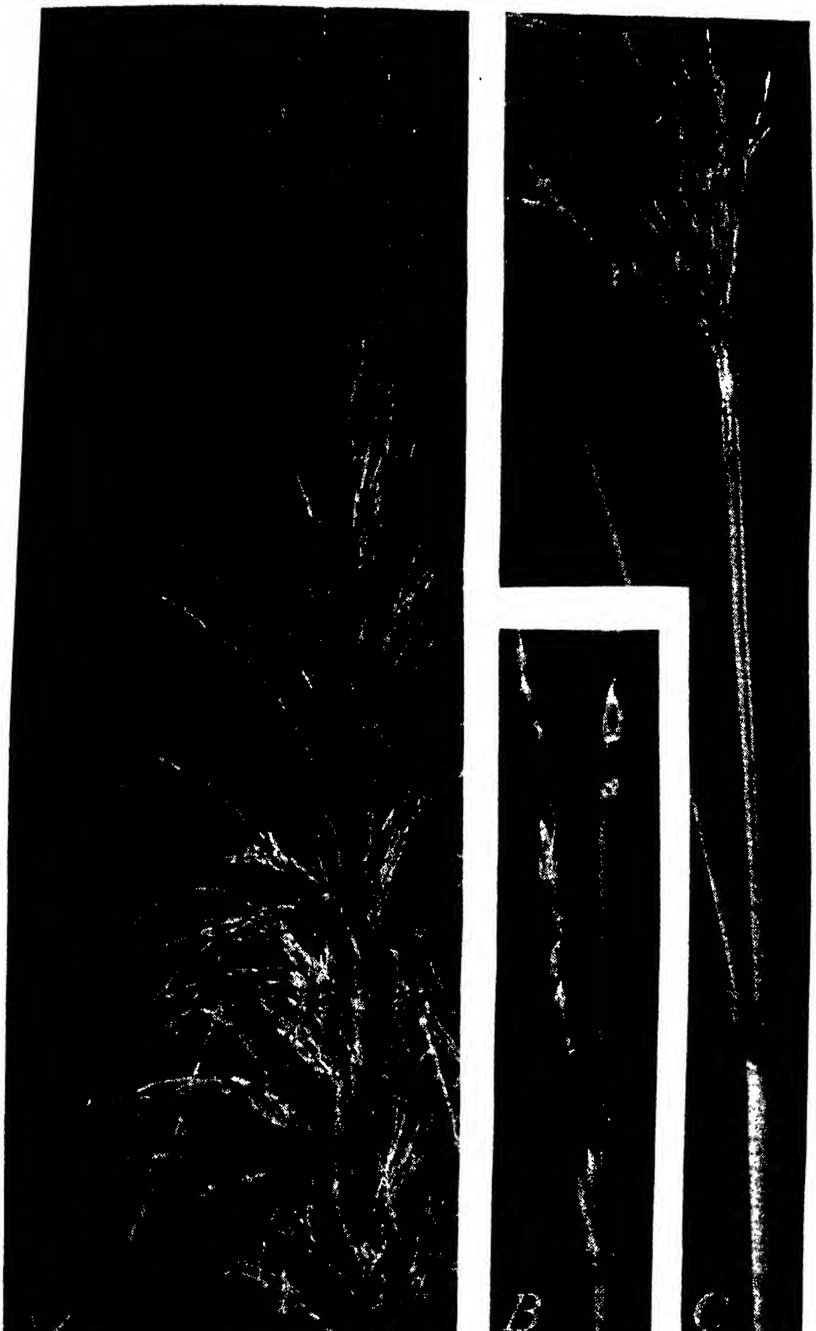


FIGURE 1.—*A*, Inflorescence of sugarcane fully expanded; *B*, lateral axis of inflorescence bearing pairs of spikelets; *C*, inflorescence in the "flagging" stage.

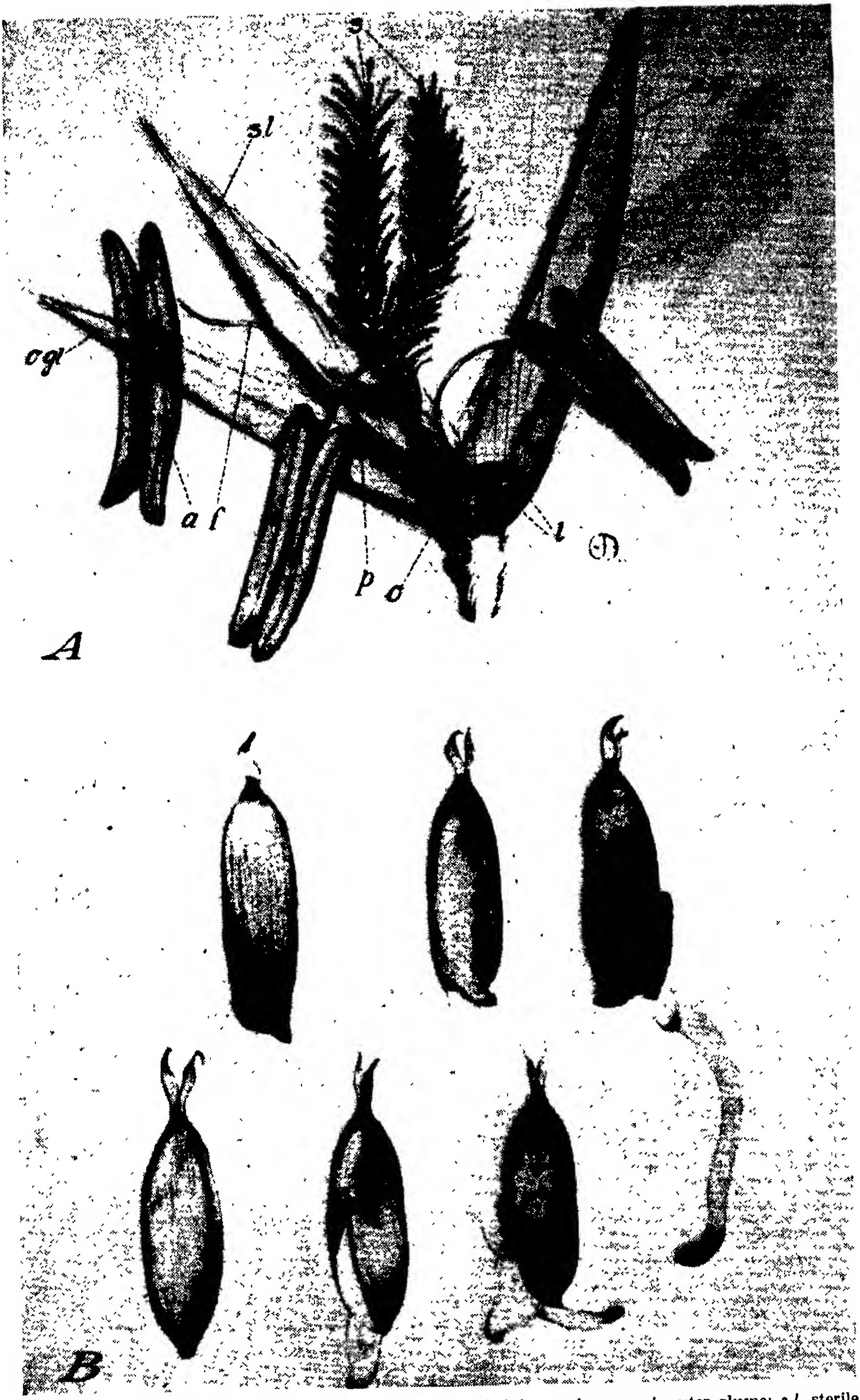


FIGURE 2.—*A*, Open sugarcane flower of variety U. S. 759; *i gl*, inner glume; *o gl*, outer glume; *s l*, sterile lemma; *f l*, fertile lemma; *p*, palea; *l*, lodicules; *o*, ovary; *s*, stigma; *a*, anther; *f*, filament of anther. *B*, Stages in the germination of sugarcane seed.

wise trips, but judging from personal observations on the food supplies carried by Papuans on coastwise trips, propagating material would be on hand to plant if new shores were reached. A more exhaustive study of the wild and cultivated sugarcanes of the numerous islands of the southern Pacific, with attention to sugarcane diseases, insects, and other biological relationships, might incidentally throw light on the wanderings of the migratory races that swarmed off in successive waves from southern Asia.[5]

The other wild progenitor of sugarcane, *S. robustum*, is limited to New Guinea and adjacent islands and Celebes, so far as is known at present; but as very few observations seem to have been made on this large and striking plant, the known range may be somewhat extended when greater interest results in more attentive observations in other places.

Cultivated sugarcane was transported westward as well as eastward from the home of the wild canes, but at a later date. By successive impacts of eastern civilization, it reached southern Spain in the eighth century and was taken to the new world by Columbus on his second voyage. It is even possible with fair assurance to designate the variety of cane that reached America first and was later given the name of Creole cane or cane of the country. Importations from Spain in 1935 include this variety, a rather small, soft, yellow cane that came to us under the name Algarobena and is now grown only for chewing. It persisted in the West Indies and in Louisiana until the first years of the past century and is accurately described by Fleischmann (*9*). Numerous other varieties have been given the name "Caña Criolla" in the Spanish-speaking countries of the Americas, or Creole cane in English-speaking countries.

It is implied and even definitely stated in many written records extending over four centuries that sugarcane is indigenous to the New World, but there are no reliable records of finding sugarcane in places not previously visited by Europeans or in contact with Europeans. No evidence of wild sugarcane growing naturally in North America is to be found, nor of any other grass closely enough related to suggest possible descent of cane from it. It is concluded that the references to indigenous sugarcane recurring throughout the voluminous early literature on the New World[6]—for example, the report by Pere Hennepin, referred to by Labat (*10*), of wild sugarcane in the country around the mouth of the Mississippi River—are based on mistaken identification of other plants, as well as on mistaken conjecture or hearsay evidence often repeated by being lifted bodily from other books. The idea of independent origin of sugarcane in places other than the natural habitat of *S. spontaneum* and *S. robustum* is corroborated neither by present botanical evidence nor by reports and writings that will stand scrutiny, and it is safe to assume that the cradle of the cultivated sugarcane is the region where these two wild species are found.

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[5] The present natives of New Guinea are a mixed race, with Papuans predominating, but included are Negritos in fairly large numbers and individuals showing definite Malayan and Polynesian characteristics. The latter are too numerous to be accounted for by importation of missionary teachers from Samoa and Rarotonga during the latter part of the past century, and New Guinea may well have been the temporary home of the people who now populate Polynesia.

[6] An unpublished manuscript by one of the present writers contains a review of the records on this subject left by early voyagers and commentators.

PRACTICES OF PRIMITIVE GROWERS OBSERVED ON A JOURNEY TO NEW GUINEA

Together with the sago, betel nut, and coconut palms, the breadfruit and Pandanus trees, and the taro, yam, sweetpotato, and banana, sugarcane is invariably associated with primitive man in Melanesia today, especially in those almost inaccessible regions where the garden culture and food quest generally remain unchanged by contact with civilized man.

As late as 1928 (*4*), immense areas in the deep interior of New Guinea were found to present pictures of primeval savagery most impressive to the observers, who confidently believed that these strange people (fig. 3) and their customs, ceremonies, and material culture represented a stage of development unique in the world today and probably not unlike that of adjacent regions 20,000 to 30,000 years ago. These areas are far from the coast and the people are not to be confused with the familiar frizzly haired coastal natives, who themselves were practically unknown until about 1850.

FIGURE 3.—Sugarcane and a sugarcane grower in the interior of New Guinea.

During this trip, opportunity for gaining knowledge of the sugarcane garden culture of the interior natives was unfortunately limited to observations lasting only a few hours or a few days at each place visited, while the observers were collecting sugarcane varieties. The perishable nature of cane cuttings made long stays impossible, and the trip over New Guinea, which was made by airplane, permitted only a cursory view of the garden routine. Nevertheless, it was possible to get a fairly good idea of Papuan cane culture by piecing together these observations and what could be observed at more leisure on the coast.

The natives of all racial types in all localities visited cultivated the sugarcane. The number of villages observed was upwards of 100 and covered the entire eastern half of the island, an area equivalent to Germany and France combined. Cane was grown from the tidewater sections—where the stools in some cases were planted individually in little mounds rising a foot above sea level at high tide—to the plateau areas and mountain slopes more than a mile above sea level.

The varieties cultivated by the natives comprised an astonishing assortment, estimated at over 100 distinct kinds. Most of them were apparently unable to maintain themselves in competition with wild vegetation, judging by the appearance of sugarcane in abandoned gardens, where the jungle invariably encroached upon and smothered out the cultivated forms. Wild sugarcane was present everywhere, the *S. robustum* along watercourses and *S. spontaneum* in swamps and uplands as well. Intermediate forms, doubtless the result of natural hybridization, were found both in wet places and in situations intermittently wet and dry.

The thick-stemmed wild forms approaching the type of *S. robustum* were mostly green in color, but yellow and red varieties were also observed. The thin-stemmed wild cane, *S. spontaneum*, was quite variable in size, habit of growth, and color. Varieties were seen with red, green, and yellow stripes in various combinations, but in general the plants were of a uniform, solid green color. The color of the flesh and foliage was also variable in the wild forms, almost all colors in cultivated examples being matched in the wild sugarcane, though not in the same combinations. The small wild plants were utilized by the natives for arrow shafts and the large, woody sorts to some extent for building purposes. Sucrose is present in the juice of wild canes of both sorts, ranging from 0.5 to 7 percent.

The principal differences between these and the varieties of cultivated cane are the increased sucrose and diminished fiber content of the latter. Because of the deficiency in fiber, the cultivated canes are structurally weak and when very tall are often seen tied together and supported by long vertical poles, with overhead horizontal connecting poles extending from one stool to another (fig. 4).

The lack of fiber is desirable; the softer the cane the more it is esteemed by the natives for eating. No refining or processing of any description is practiced, and aside from ceremonial uses of varied character, the stalks of the cultivated varieties are utilized only for chewing and sucking, after they have been broken into convenient lengths.

Transition from the wild to the cultivated forms is assumed from examination of the varieties collected in native gardens, which exhibit a uniformly graduated range of forms. Just how this transition has been brought about can only be guessed, and in any particular example it is not certain whether the intermediate characters are the result of recent hybridization or previous selection of variants from the primitive forms. That variations occur through actual diversities in the germinal substance of sugarcane cannot be doubted, and when such variations are found they are readily perpetuated by vegetative reproduction.

In the case of sugarcane, therefore, it is easy to reconstruct the process by which primitive man has selected and maintained superior varieties from the profusion of wild forms everywhere at hand. It is only necessary to assume that he had powers of observation and consciousness of the significance and utility of what he observed. Observations of the present Papuans amply demonstrate that primitive man had these characteristics and used them in the field of horticulture.

As an example of the surprising perspicuity of these gardeners, who correspond to those in the Neolithic era, an incident of the trip

is worth recording. Two varieties of quite different aspect were collected in the same village. By dint of pantomime and much unintelligible shouting back and forth, it was hopefully thought that the

FIGURE 4.—Sugarcane in a Papuan garden. The canes are grown for chewing; since they are structurally weak, they are supported by upright poles connected by horizontal poles running from one stool to another.

native names of these varieties, together with names of a half dozen others in the same garden, were finally obtained. All the other names were totally different, but the two varieties mentioned bore names that were identical except for the last syllable.

The canes were attentively examined on the spot, and the minute characteristics of the buds were found to be the same, good evidence that one was merely a color variant of the other, although at first sight they had seemed strikingly different. It seemed obvious that the natives had seen the relationship, probably by observation of the stool in which the variant occurred, and when the plants were separately propagated the relation was recognized by what corresponded to scientific binomials.

No such explanation could be obtained from the natives themselves, however. Even in the case of Motuans and other coastal tribes, who now speak pidgin English, it is useless to attempt to wring from them any but the most matter-of-fact explanations, and to propound abstrusities is manifestly unfair. It is evident that what insight we gain into the processes by which utilitarian plants were developed must come from unexpected or chance evidence, as in this case, or from evidence that is indirect.

Primitive Agriculture Throws Light on the Origin of Cultivated Cane

In addition to the evidence of conscious selection of economic plants by the superior individuals among these savages, there was evidence of the development of a horticultural routine in which magic was freely mixed with agricultural practices that we flatter ourselves are highly modern.

The water requirements of sugarcane were respected and provision was made in various ways to meet them. In the tidewater section of the Kikori River and its numerous tributaries, where little dry land suitable for cane culture was available, the cane was seen planted on the tops of tubular mounds several feet high, thrown up from the mud flats by a large crustacean, not captured but seemingly a sort of glorified shrimp. Here the opportunist gardener, utilizing varieties tolerant of the slightly brackish water, found a way to accomplish both irrigation and drainage with the rise and fall of the tide. An ingenious herringbone system of drainage ditches was seen from the air in a garden on the Fly River about 100 miles from the coast. Drainage is, of course, more important than irrigation, but at times irrigation systems, including crude flumes extending across small ravines, are utilized.

Rotation of crops in the miniature gardens—few being more than an acre in size—seems not to be practiced in New Guinea, where the population is sparse and land is plentiful; but rotation of gardens, that is, abandonment of old sites in favor of new clearings laboriously made with stone axes, is universal. This has been ascribed to the fact that it requires less effort to fell trees than to fight the weeds that creep into the clearings, but the lusty growth of his taro, bananas, and sugarcane on virgin land cannot fail to have impressed the observant native.

It was noticed that the low heaps of wood ashes, left after burning the brush and logs from new clearings, were in some cases apparently selected as spots for planting, but whether by chance or because of an idea of the value of ashes as plant food could not be ascertained. The latter seems unlikely. The fight to control pests was apparently limited to taking precautions against the bush pig, wallaby, cockatoo, flying fox, rat, and other predatory animals by building fences and

by supporting and binding the canes together and wrapping them in banana leaves.

Most of the operations in the garden culture of sugarcane are so obviously rational and in keeping with good modern practice that certain backward tilling and cultivating methods stand out strongly by contrast. The garden is almost invariably disorderly as to rows and arrangement of plants, and there is no attempt at tillage. The typical garden (fig. 5) has taro, yams, bananas, sweetpotatoes, and sugarcane all growing together in the greatest confusion. The only implements of the gardener are his stone ax for clearing and the digging stick—a straight stick or pole sharpened to a point at one end. This is thrust into the soft earth, the cutting is inserted in the hole, and that is all.

FIGURE 5.—A typical Papuan garden. Cleared from the jungle with stone axes, these gardens grow taro, yams, bananas, sweetpotatoes, and sugarcane in a confused medley.

It is evident from this brief description that though the most primitive types of men in existence today practice the crudest kind of tillage, or none at all, because of lack of tools, yet they exhibit surprising familiarity with the requirements of sugarcane plants and a detailed knowledge of the plants themselves. The evidence of observation careful enough to enable them to distinguish varieties and indicate their origin by the names used seems sufficient to justify the assumption that they also consciously select better forms. Since plants that are probably the wild progenitors of cultivated cane are at hand in great profusion and variety, it is not too much to ascribe to these people the development of the cultivated sugarcane as we know it today.[7]

[7] It has been mentioned that magic, the use of symbols or sorcerer's specifics, and procedures and observances of the weirdest and sometimes the most ludicrous or ghastly character, are woven in with the rational routine. To the natives, one is apparently as indispensable as the other. This endless variety of magical practices impresses one with the elaborate mental gymnastics of these people, to whom we are indebted for more than has been generally acknowledged. Those who may wish to pursue further the subject of Papuan magic in garden culture are referred to the exhaustive and scholarly treatise by the present Government anthropologist (20).

The varieties collected in New Guinea include some that have proved to be of great economic importance when planted commercially elsewhere. In general they are very colorful, with many striped and variegated examples, testifying to the savage's liking for brightly colored objects.

It should be emphasized that this brief description of primitive cane culture is a composite of observations among many divergent tribes and that the tribes, as well as the individuals in a particular group, differ in mental attainment and physical makeup, just as similar populations do elsewhere; also that these people have been used as illustrating the probable course of development of cane from wild to domesticated types. In most cases the latter eventually became totally unfit to compete under natural conditions with the more aggressive forms of plant life. Throughout the extensive areas in Asia where the wild forms occur, cultivated varieties doubtless arose in a like manner.

The Improvement of Varieties by the Method of Trial and Error

THE earliest records of the utilization of sugarcane by civilized races are those of the people of China and what is now British India. Within comparatively recent times many of the important commercial varieties of sugarcane in these areas were of the slender types, corresponding to the slender wild cane indigenous there; and this is true even today. The thick-stemmed tropical varieties are not newcomers in continental Asia, but they are more generally restricted to the lower latitudes and are probably migrants even there, having been brought within historic times from regions closer to the Equator, where the thick-stalked wild cane grows naturally.[8]

The part sugar has played in the stimulation of commerce between widely separated lands, the development of trade routes, the infiltration of the white race into the Tropics, and the development of tropical and subtropical countries, is a fascinating subject, but here it can only be mentioned in passing. Probably no other agricultural commodity has influenced commerce and colonization more than sugar. During the long period characterized by extension of sugarcane culture eastward and westward around the broad equatorial belt, and the subsequent gradual development of large-scale plantation methods as contrasted with the previous subsistence garden production, there seems to have been little progress in the direction of improvement of the plant itself. All this time, 2,000 years or more, there is no tangible evidence and there are no written records indicating that the possibility was thought of, although there is abundant evidence that attention was given to the adaptability of the plant to different conditions, and to improvement in cultural methods. During this period, beginning roughly with the Christian era, the attitude was one of willingness to accept the cane plant as it is.

[8] A voluminous record of sugarcane culture and manufacture of sugar in historic times has been prepared by Von Lippmann (*11*) drawn from writings of ancient chroniclers and extending down to writings of our times. The interested reader is referred to this elaborate, detailed compilation for an authentic account of sugarcane culture by the civilized races as recorded by historians, poets, and biologists.

Numerous reasons suggest themselves to account for this. There were apparently unlimited areas for expansion and there was an increasing world demand for sugar, the supply, in general, never quite reaching the demand. The energy of those engaged in the production of cane was expended in pioneering and opening new lands for cultivation. Together with the multitude of problems incidental to manufacture, transportation, and marketing, this left no time for contemplation of such abstruse ideas as the possibility of interfering with nature, or even questioning the perfection of her handiwork as exhibited in the natural or original varieties of cane. Again, the number of varieties that found their way to particular producing areas was limited. Sometimes planters in large areas relied on a single variety. This situation was not one to stimulate thought on the possible improvement of varieties. This attitude of laissez faire, or let things alone, continued until the early part of the ninteenth century, when the first evidence comes to light indicating that the question of improvement began to be debated.

An interesting comment by one of the more enlightened planters of the period, Leonard Wray, who had experience both in British India and in Jamaica, is worth recording here. On the subject of searching for sugarcane seed—the existence of which was doubted—with an eye to possible improvement, he says (*21, p. 33*):

> I must own I cannot well explain why planters should be so very anxious to obtain possession of cane seed; surely they can scarcely expect to obtain a finer variety of cane than the Otaheite or Salangore!—a cane that, under favourable circumstances produces from two to three tons of dry sugar per acre!

Doubtless Wray referred not to average but to maximum yields. "Under favorable circumstances" these maximum yields, during the past decade in our own period, have been as high as 20 tons of dry sugar per acre.

At least three factors that developed during the nineteenth century are responsible for the gradual growth of the idea of planned interference with the cane plant itself, to bring about directed improvement by selection and breeding. These three factors were disease epidemics, commercial competition, and the general advance in biological science.

DISEASE EPIDEMICS—THE FIRST STIMULUS TO IMPROVEMENT

Diseases of the sugarcane are not new; quite possibly they are as old as the cultivated or the ancestral forms of cane; but for two reasons they did not result in attempts to improve sugarcane until comparatively recent times.

Under primitive conditions, when it is confined to very limited natural stands or small cultivated patches separated by miles of other vegetation, the sugarcane has been observed to be singularly free from diseases, although a variety of diseases existed in one patch or another and in exceedingly small amounts. For the most part, epidemics are due to favorable weather and other factors resulting in an increased population of disease organisms. This increased population is dependent on the number and the closeness of the host plants. If the latter are not in continuous areas but are isolated in one way or another, one of the requirements for a widespread epidemic is lacking. If there is an epidemic under these circumstances, it is local in character and spends itself without attracting much attention when the conditions

favoring the disease pass. On the other hand, where plantings of the host are massive and continuous over hundreds of square miles, the same general conditions result in enormous losses and in no uncertain way provoke thought on the cause of such disasters and the possibility of avoiding them.

During the nineteenth century and up to the present time, many of the most important producing countries reached the saturation point in sugarcane cultivation, every acre suitable for the crop—and many that are unsuitable—being utilized. Thus diseases have been more widespread and the economic losses immeasurably greater than at any time before.

Disease Relentlessly Follows the Migrations of Cane

The second reason for failing to recognize the importance of diseases and for the tardy application of thought and effort to the search for disease-resistant varieties was that frequently the cane was taken from its primeval home without disease organisms, or at least without the full complement of diseases that cane is heir to, and was established in remote places free from disease. But with increased transportation facilities and the development of a greater volume of commerce between countries, diseases relentlessly followed with subsequent cane plants or cuttings.

The most striking examples of this delayed overtaking of the cane by diseases are furnished by certain of the virus diseases, which have broken out in important commercial producing areas in the New World only in the past 30 years.[9] After more than four centuries of cultivation in the United States the number of diseases present here is noticeably less than in India, the East Indies, the Philippines, and Australia. The great variety of diseases in the latter countries, contrasted with the relatively few diseases in all other countries of the world where sugarcane is grown, seems significant in suggesting as the place of origin of the sugarcane plant the area where the number of diseases is greatest. Indeed, if confirmation of the place of origin of sugarcane were needed, the evidence furnished by the number and variety of diseases in different parts of the world, presenting as it does a picture of successive radiating impacts of disease organisms diminishing in variety but not in intensity, would seem to supply it. For reasons that are apparent and need not be dwelt upon, the earliest migrations of cane, those to the small, widely separated South Pacific islands, are the ones in which overtaking of the cane by the diseases representing primitive associations are the longest delayed.

The earliest records of severe and widespread epidemics are concurrent with the intensive and massive cultivation of sugarcane in the nineteenth century. About 1840, in Mauritius and Reunion, there was complete failure of the Otaheite cane, which had been the backbone of the industry in those islands since its introduction from Tahiti in 1788. It is not possible to state the exact nature of the outbreak, but it seems to have appeared suddenly and to have run its course quickly. Because it was referred to as "degeneration" of the variety, an idea which has persisted in other countries to the present day, the logical course was to abandon the decadent variety and replace it with others that had not "run out," and this was done.

[9] Because mass recovery has been observed in the case of mosaic, there is a possibility that the disease had existed in the areas before, and that these are reintroductions.

The same remedial action was taken about 1860 in Brazil, when an epidemic supposedly caused by *Bacterium vascularum* played havoc with the Otaheite variety. It was replaced by Cavangerie and other varieties selected from a considerable number brought to Brazil to reestablish the industry. The variety Otaheite was almost completely wiped out in Puerto Rico about 1872. During the course of the epidemic, it was noticed that in mixed plantings, where Rayada and Cristalina were included with Otaheite, the two former varieties were not severely attacked. Again the remedy resorted to was the substitution of varieties provided by nature.

Thus far no effort had been made to cross-breed for resistance, as infertility of the sugarcane seems to have been generally accepted. The next historic disease outbreak, however—the sereh epidemic in Java, beginning in 1880—was destined to inaugurate a new and useful tool for the plant scientist, the "nobilization" of hardy but otherwise inferior varieties by successive crossing and back-crossing with the so-called noble varieties. The latter, varieties of *Saccharum officinarum*, are as a rule susceptible to disease but are of good quality and fine, aristocratic appearance, hence "noble," according to the Dutch scientists who introduced the English word into the Dutch language—a happy selection of a term with definite connotations.

BEGINNING OF THE IDEA OF NOBILIZING SUGARCANE

This was a gradual development, dependent upon a number of complementary discoveries and participated in by various investigators through a period of several decades. Calamities that threaten the very existence of the industry seem several times to have provided the stimulus for progress in the understanding of fundamental biological principles, and the sereh epidemic is a noteworthy example.

At the time of the outbreak, the leading variety in Java was the Zwart Cheribon (Louisiana Purple), which had little natural resistance and was the principal sufferer. The disease was specially refractory in yielding to study, and even today the etiology is obscure. It was discovered, however, that certain varieties, notably Chunnee brought from British India, were resistant. With this fact and the discovery—or more properly the presenting of convincing evidence—that certain varieties of sugarcane develop viable seeds, the means for solution of the sereh problem suggested themselves.

Chunnee is a very thin cane somewhat resembling the wild *S. spontaneum*. The planters of Java, accustomed to the large-barreled, heavy-yielding tropical varieties, were prejudiced against it. As it was totally unacceptable as a substitute for the Cheribon and Preanger, crosses were attempted between these and the Chunnee. Some of the resulting hybrids were more to the liking of planters in habit and conformation, but still somewhat disappointing.

Meantime, the industry was maintained because it was found that susceptible varieties grown in the mountains did not suffer from sereh, and seed cane from this source planted in the valleys and on the coastal plain gave rise to plants acceptable to the mills as plant cane or first-year crops. However, the ratoons arising from the stubble of these plant canes suffered severely from sereh. An expensive readjustment in methods of culture, involving transportation each year of cuttings or bibit from the higher elevations to the lowlands,

was necessary. This enabled the industry to survive, but naturally it was distasteful to those engaged in commercial cane husbandry.

A wild-growing or semiwild plant unaffected by sereh was found on the lower slopes of Tjeremai, an extinct volcano. It was presumed that this interesting plant, called Kassoer, resulted from natural crossing of Zwart Cheribon and glagah, a form of *S. spontaneum*. The possibility that it was a disease-resistant cross provided a clue for the utilization of glagah as well as Kassoer itself in crosses—a process later to become known as nobilization of the more primitive, hardy, and disease-resistant forms of sugarcane. Following this, hundreds of thousands of seedlings have been produced and carefully tested by crossings and repeated back-crossings with numerous superior but susceptible noble varieties, and the system or method of breeding has resulted in varieties not only equal but infinitely superior to the Zwart Cheribon in the days before the sereh epidemic. The successive steps in nobilizing sugarcane are illustrated in figures 6 to 10, inclusive.

The impetus given to improvement of the cane because of these disease epidemics has continued to the present day, but it cannot be claimed that they are solely responsible for such efforts in modern times. Other factors have played roles of almost equal importance.

COMPETITION BETWEEN SUGAR-PRODUCING COUNTRIES AS A STIMULUS TO IMPROVEMENT

In recent years, particularly since the close of the past century when the question of overproduction of sugar has become acute from time to time, commercial competition for markets has stimulated work on improvement of the cane plant. It is obvious that lower costs of production resulting from efficiency in the field would bring an advantage to the countries successful in producing the crop more cheaply than their competitors. This has been generally recognized and efforts toward improvement of the plant have been intensified in some quarters. At the same time it must be remembered that world overproduction brings low prices, and budgets for research suffer in the lean years, so that technological research has been retarded in the countries hardest hit during the present depression.

It may not be out of place to point out that the low world price for sugar resulting from overproduction followed hard on the close of the World War, nearly a decade before the general depression in business. In many sugar-producing countries the forced economies resulted not only in diminution of research, but in neglect of field practices long recognized as indispensable for permanent agriculture. Where research was continued, it is noticeable that it has been productive of valuable results. It may not be altogether a coincidence that practically all the knowledge we have of the principles of genetics as applied to sugarcane has been accumulated since inauguration of "tooth-and-claw" competition for the sugar markets of the world.

THE EFFECT OF GENERAL ADVANCES IN THE BIOLOGICAL SCIENCES

It cannot be said that any economic consideration supplied the motive for the revival of learning that began in the late sixteenth century. Many of the ideas on biology enunciated by the pundits of those times

FIGURE 6.—Nobilization of wild sugarcane. A variety of *Saccharum spontaneum* found in New Guinea. The canes are slender and deficient in sugar but vigorous, erect, and prolific. A good type to nobilize. Mated with the type shown in figure 7, it gives seedlings like the one illustrated in figure 8.

found confirmation in the careful researches of biologists, some of whom were doubtless stimulated by this pioneering. Although not conceived in the modern method of hypothesis, deduction, and experiment, some of the eloquent writings of Bacon (*1*) on the role of

science in the ideal commonwealth, in which development of new varieties of plants and animals by crossing is mentioned, may have served to crystallize and publicize ideas that provoked others to active, fruitful experimentation.

It is beyond the scope of this short survey to trace such developments, but it should be mentioned that the culture of sugarcane, the first field crop grown on a scale requiring thousands of acres in individual enterprises, at an early date engaged the attention of many men familiar with the writings of the philosophers and scientists. The recorded observations and experiments of Wray (*21*) indicate thoughtful consideration of many of the biological problems involved, including the possibility of improvement of cane by breeding, and he is typical of a considerable proportion of the practical planters of his day.

FIGURE 7.—Nobilization of wild sugarcane; cultivated sugarcane, a variety of *Saccharum officinarum* with high sugar percentage found in New Guinea. Note the large stalks, relatively few in number, contrasted with the wild variety illustrated in fig. 6. Unlike the latter it has little resistance to most diseases.

Wray's ideas were sometimes fanciful—for example, his attempts to stimulate the production of seed in the sugarcane by dusting the pollen of sorghum and maize on cane tassels. With luck, he might have effected the first controlled intergeneric cross with sugarcane, but he failed and was led to a wrong conclusion as to the viability of sugarcane seed. It was not an altogether fruitless attempt, however, as the publication of his negative results directed attention to the problem, and publication of contrary views on seed production, based on observations by other planters, soon followed.

An eagerness to keep abreast of scientific thought in agriculture characterized the sugarcane planters long before the days of cooperative endeavor and the beginning of research endowed by the State. This appreciation of the advantages to be gained by attention to the general advances of science played an important part in preparing the way for recognition of the value of breeding.

Research Institutions Enter the Picture

The stimulation due to scientific advances was partly responsible for the formation of associations of planters and agricultural societies. The inauguration of research institutions was an outgrowth of the meetings of groups which gathered to discuss problems and extend

FIGURE 8.—Nobilization of wild sugarcane: A hybrid resulting from crossing the types shown in figures 6 and 7. This is the first step in nobilization of a wild cane. The hybrid is vigorous, prolific, and of excellent habit but of no commercial usefulness because of low sucrose percentage.

information by means of reports and periodicals. Beginning in the nineteenth century, these institutions provided the means for sustained attack on problems of cane husbandry that formerly had to be chinked into the crevices of an overburdened commercial routine in the case of most planters. Not less than 100 such institutions have

come into existence, about half being privately supported by individual estates or plantations and the rest by governments or associations of planters. Only a few of the experiment stations, public and private, which give some attention to sugarcane improvement have devoted to breeding the persistent effort necessary for the production of valuable varieties, and still fewer have contributed to methods and principles in breeding sugarcane.

The stations which, if not the earliest of those giving attention exclusively to cane, at least carried on investigations acknowledged to mark the beginning of sugarcane breeding were located in Java and Barbados. They were established almost simultaneously and began work in 1886. Two stations in Java, those at Tegal and Kagok, date from that year and the Proefstation Oost Java at Pasoeroean from the year following. These were all privately supported by associations of growers. The one in Barbados was a Government institution, attached to the Boys' Reformatory School at Dodds in order to utilize the labor available there, and was called the Botanic Station.

FIGURE 9.—Nobilization of wild sugarcane: Cultivated sugarcane. A variety of *Saccharum officinarum* formerly grown commercially in Louisiana. It is subject to injury by disease but is of good quality and early in maturing. The latter characteristic is important in Louisiana, so the variety is desirable for further improvement of the hybrid shown in figure 8.

Up to the time of establishing these stations the seed of sugarcane had not been figured or described by botanists, although the flower had been excellently described and illustrated. The existence of functioning or viable seed was doubted by responsible and careful observers who had sought for them in vain. It is true that reports on the natural occurrence of seedlings in Barbados, Java, and elsewhere had been made for many years, but with no evidence of actual handling of the seed or planting it, and claims respecting these chance natural seedlings were usually met with ridicule. In the light of present knowledge of the development of flower and seed in sugarcane it is not difficult to understand this early skepticism. The varieties grown commercially bloomed irregularly and the percentage of the minute seeds capable of germinating was extremely small.

In 1889 Dr. Benecke reported on work which showed clearly that Dr. Soltwedel had observed the occurrence of true seed and its germination in 1887 at the Central Java Experiment Station in Semarang.

In the same year J. B. Harrison reported on similar observations made by him and J. R. Bovell early in 1888 at the botanic station in Barbados. The 6 months separating the time of these independent observations, reported the same year, is attributable to the fact that in Java, south of the Equator, sugarcane blooms from May to July, and in Barbados, in the Northern Hemisphere, it blooms from November to January.

The independent researches of these two groups of investigators were of great significance to the cane industries of their respective countries, and directly or indirectly were of far-reaching importance in many other important cane-producing countries. In Java they laid the groundwork for an increase in the production of sugar per unit of area amounting to over 300 percent in the period from 1885 to 1925, and this cannot be said to represent the maximum yield possible.

FIGURE 10.—Nobilization of wild sugarcane: A hybrid obtained by crossing the variety illustrated in figure 9 with the hybrid type shown in figure 8. The result is a superior high-yielding economic plant, relatively high in sugar percentage, relatively early in maturity, and of good habit of growth. The materials and steps in producing this seedling are illustrated in figures 6 to 10.

Not all of the increase can be credited to the improvement of varieties by breeding. In fact, from the year 1844 to the beginning of the period when systematic breeding began, a similar increase in yield had already been accomplished by other means. The total increase in yield from 1844 to the present time is close to 1,000 percent. Breeding has been the main factor during the past four decades, however, and the investments in breeding studies are acknowledged to have paid handsome dividends. Certain important sugar countries, notably Cuba, have not taken advantage of the possibilities in breeding cane, and the improvement of the cane plant by scientific methods has lagged there.

Modern Methods of Improving Sugarcane and Their Results

PRIOR to the establishment of the first sugarcane-breeding stations in Java and Barbados, the improvement of sugarcane was effected by means of selection from the world material. In the

Tropics selection was confined to the varieties of *Saccharum officinarum*, or noble canes. Until recent years most of the sugarcanes of commerce were varieties of this species—Creole, Otaheite, Black Cheribon, and so forth. In the subtropical areas of India and Indochina, commercial varieties were selected from *S. barberi* (the Indian canes such as Chunnee, Mungo, Kansar) and from *S. sinense* (the varieties Uba, Kavangire, Cayana, and so forth, more commonly known as Japanese canes). These varieties have never had as wide distribution as those of *S. officinarum*, but they have played a part in the modern improvement of sugarcane, and they have been used in certain areas to save the sugar industry when the noble canes were stricken by disease.

FIGURE 11.—Wild sugarcane, a variety of *Saccharum robustum* found in New Guinea. Representatives of this species have been found in Celebes and more recently (1935) in the New Hebrides. The usefulness of *S. robustum* in breeding sugarcane has not yet been demonstrated, but by crossing and back-crossing with "noble" varieties, some seedlings of immense size and fair quality have been produced. Contrast the size of this plant with that of the wild variety shown in figure 6.

Besides the cultivated species, two wild species are used in the modern improvement of sugarcane by hybridization—*Saccharum spontaneum* and *S. robustum*. The former is the more important because its hybrid seedlings are adapted to a wide range of soil and climatic conditions, and from it are inherited immunity to mosaic and sereh, diseases of major economic importance. The actual value of *S. robustum* (fig. 11) is not known because it is a new species collected from the wilds of New Guinea in 1928 by E. W. Brandes and J. Jeswiet, so that there has not been sufficient time to test it. Its hybrid seedlings produced at Canal Point, Fla., and in Australia and Hawaii show promise, and there is no doubt that in combination with other species it will be of value in breeding new types of commercial sugarcane.

TABLE 1.—*General characteristics of sugarcane species*

Species	Sucrose content	Maturity	Fiber content	Stalk girth	Width of leaves	Adaptability	Reaction to—			Remarks
							Sereh	Mosaic	Smut	
S. officinarum	High	Variable	Low	Large	Wide	Confined to Tropics.	Susceptible	Susceptible	Moderately susceptible.	Some varieties resistant to Fiji disease and gummosis; cultivated species.
S. sinense	Intermediate	Early	High	Medium to slender.	Medium to narrow.	Wide	Immune	Some varieties susceptible.	Susceptible	Cultivated species; great vigor.
S. barberi	do	do	do	do	do	Temperate and sub-Tropics.	do	Susceptible but tolerant.	Moderately susceptible.	Do.
S. spontaneum[1]	Very low		Very high	Very slender	Narrow	Wide	do	Immune	do	Wild species; great vigor; susceptible to downy mildew and leaf spot.
S. robustum[1]	Low		do	Medium to large; great length.	Medium	Natural range confined to the Tropics but appears to be adapted to a wide range of conditions.	Undetermined	Susceptible	Undetermined	Wild species; great vigor.

[1]Only *S. spontaneum* and *S. robustum* are able to maintain themselves in a wild state.

The world material, comprising hundreds of varieties, is grouped under five species. The species and their general characteristics are listed in table 1.

Regarding characteristics not included in table 1, it may be said in general that the varieties of *S. officinarum* are susceptible to most of the major diseases and are not adapted to adverse conditions of soil and climate.

The varieties of *S. sinense* are immune to sereh disease but do not react uniformly to mosaic, some being susceptible and others apparently immune. These varieties are very susceptible to smut. They possess great vigor and are adapted to a wide range of conditions.

The varieties of *S. barberi* are of about the same vigor as those of *S. sinense*, and are adapted to culture under the more severe conditions of the sub-Tropics. They are immune to sereh but susceptible to mosaic; however, these varieties are not severely injured by this disease but are tolerant of it.

The varieties of *S. spontaneum* are immune to mosaic and sereh, but are attacked by smut, downy mildew, and several leaf spots. They are exceedingly vigorous, however, and are capable of maintaining themselves in a wild state.

S. robustum is similar to *S. spontaneum* in that it can maintain itself in a wild state, but it is susceptible to mosaic. However, it has better agronomic characteristics than the other wild canes.

From this review of the general characteristics of the sugarcane species, it is obvious that for hybridization with noble varieties, *S. spontaneum* should be preferred because of its immunity to disease and great vigor. Next to it are *S. barberi* and *S. robustum*. *S. sinense* has desirable characteristics, but as its progenies are usually very poor it has been used very little in breeding. The true value of the species is not known. In a few combinations it has given seedlings of promise. As knowledge about it increases, it is very probable that it will prove to be of value in breeding new types of seedlings.

The natural species and varieties of sugarcane and the hybrid varieties available for breeding work, with their characteristics, are given in the appendix (pp. 612–624).

PECULIARITIES OF SEXUAL REPRODUCTION IN SUGARCANE

In commercial practice sugarcane is propagated asexually by means of cuttings of the stalk. These cuttings are commonly called seed cane. When a variety is propagated by cuttings it remains constant and true to type. In contrast to commercial practice, reproduction in breeding sugarcane is by sexual means from true seed. As in apples, potatoes, and some other plants, no variety breeds true from seed. Every seed produces a distinct variety.

The inflorescence of sugarcane is an open-branched panicle. There are hundreds of minute flowers in a panicle. The flowers are in pairs, one sessile (without a stalk), the other pedicellate (attached to a stalk), both perfect and awnless (fig. 1).

While the flowers of all varieties are perfect, with both male and female organs (fig. 2), many of the varieties do not produce fertile pollen. Thus the varieties may be divided into two general classes—those that produce fertile pollen and eggs, and those that produce fertile eggs but sterile pollen. Very few, if any, varieties are com-

pletely sterile except under extreme conditions. Varieties that produce fertile pollen are self-fertile and may be used to produce selfed seed, or they may be used to pollinate varieties that have sterile pollen, thus giving cross-bred seed. In general, varieties that produce an abundance of fertile pollen are called males and those that produce little or no fertile pollen are called females.

The fertility or sterility of the pollen is not always a constant characteristic of a variety. Varieties which have fertile pollen in one locality may have sterile pollen in another, and some varieties change from year to year depending on weather conditions preceding and during flowering. Other varieties are rather constant in their behavior. In addition, there are a few varieties that produce fertile pollen but are apparently self-sterile.

The Technique Used in Crossing

At the present time emasculation [10] of the flowers of one variety before pollinating is not practiced. The method was used to some extent in Barbados, Java, and Queensland, but the skill required, the uncertainty of the results, and the small number of seedlings obtained have prevented its extended use. The general practice now is to use the entire inflorescence as a unit. In making a cross between varieties or species, the female chosen is always one that has sterile pollen. Thus there is no possibility that this plant can fertilize itself. Since the entire inflorescence is used as a unit, the technique of crossing two varieties is rather simple. The female variety is grown in or moved to an isolated place so that chance cross-pollination is avoided. The male tassels are cut with several mature joints of stalk and are bound to the female tassel in such a way that the flowering parts of the female are covered by two or more male tassels. The tassels are not covered by bags. Pollination is continued for 6 to 10 days.

In Java, where successful cane breeding has been carried on for 50 years, the cut end of the stalk of the male tassel is placed in a jar of water. Since the tassels remain viable in water for 1 or 2 days at the most, they are renewed daily during pollination. The female inflorescences or "arrows" are left attached to the parent plants in the field. After pollination, the female tassel remains in the field until the seed is mature. This method is known as the open-cross method.

The method used in India is quite different. A large number of stalks of varieties in the early flowering stage are rooted by fastening a container filled with earth and kept moist to the middle of the stalk. In a short time the canes form a good root system in the pots. When flowering begins, the cane is severed below the pot and transported to a protected place. Crosses are made by bringing the desired male and female varieties together. Since each stock is rooted in a pot, it can be kept alive until pollination is completed and the seed matures.

While the Javanese and Indian methods are very successful, they both involve a great deal of labor and are adapted only to countries where labor is cheap. The Javanese method also requires a large number of male tassels.

Breeding stations in countries where wages are high and station budgets are limited have in general adopted the Hawaiian sulphurous-acid method of preserving the tassels (*13*, *19*). This method is a major contribution to the technique of sugarcane breeding. When

[10] Removal of the stamens, the organ that bears the pollen or male germ cells.

in the proper stage of development for crossing, the male and female tassels are cut with several feet of stalk attached and placed in a vessel containing a solution of 0.01 percent of sulphurous acid and 0.01 percent of phosphoric acid. The vessels containing each cross are isolated and left until the seed matures, which usually takes from 20 to 30 days. Fresh solution is added daily to replace the solution taken up by the stalks, and every week the solution is renewed. When the method is used in open crosses, the female is left growing in the field and the male tassels are preserved in the solution.

Most varieties keep very well in this solution, and the few that do not, if female varieties, can be left in the field or planted in isolated places; if male varieties, the tassels can be renewed when necessary. By this method it is possible to carry on an extensive breeding program with a minimum of labor.

The capricious nature of the sugarcane plant with regard to flowering makes it very difficult to carry on a definite breeding program. The only definite thing about flowering is that it is seasonal and seldom occurs outside the Tropics. The flowering season in the Northern Hemisphere is during the winter months and in the Southern Hemisphere during the short-day period which corresponds to our summer months. Some varieties have never been known to flower. Some flower nearly every season, but during a particular season may not flower at all, or only sparsely. Others may flower only once in 5 or 6 years. Certain crosses may not be possible because the two varieties flower at different times or because both are of the same sex.

The one great advantage the sugarcane breeder enjoys is vegetative propagation. Once a variety is obtained, it can be increased and perpetuated true to type by cuttings. It is not necessary to purify the type so that it will come true, as is the case with plants propagated from seed.

The methods of breeding vary somewhat from station to station. However, they have many points in common so that a review of methods and results at a few stations in different parts of the world will show the essential features of the improvement of sugarcane by hybridization. The world sugarcane-breeding stations are listed in tables 4 and 5 with their past, present, and projected work, personnel, and expenditures. Much of the information from which the material in tables 4 and 5 was assembled was derived from answers to a questionnaire sent to sugarcane breeding stations. In a few instances the replies arrived too late to be included.

BREEDING WORK AT THE JAVA STATION (1886)

The Java sugarcane-breeding station is notable for two lines of crosses—those between *S. officinarum*×*S. barberi* and *S. officinarum*× *S. spontaneum* (*14*).

Kobus crossed Black Cheribon, the chief sugarcane then cultivated in Java, with Chunnee, a variety from British India. His object was to obtain hybrids with a high sugar content, the size of Black Cheribon, and the vigor and sereh resistance of Chunnee. The seedlings were immune to sereh, but the sugar production did not equal that of the noble parent. In addition, they were susceptible to mosaic, though rather tolerant of the disease. Great success was attained, however, with the cross of the noble varieties Black Cheribon and Gestreept Praenger×Chunnee. Seedlings from these crosses,

P. O. J. 213,[11] *P. O. J. 234, P. O. J. 36,* and *P. O. J. 36–M,* were extensively cultivated in Louisiana, Argentina, Taiwan, and British India.

Later, Kobus crossed the F_1 or first hybrid generation seedlings with different noble varieties and obtained progeny with larger stalks and higher sugar content. But these varieties were not very hardy and none of them was as commercially successful as the F_1 seedlings.

Moquette and Wakker crossed Black Cheribon with Kassoer. They assumed that Kassoer was a wild cane, a botanical species of sugarcane. It has since been shown that Kassoer is a natural hybrid of

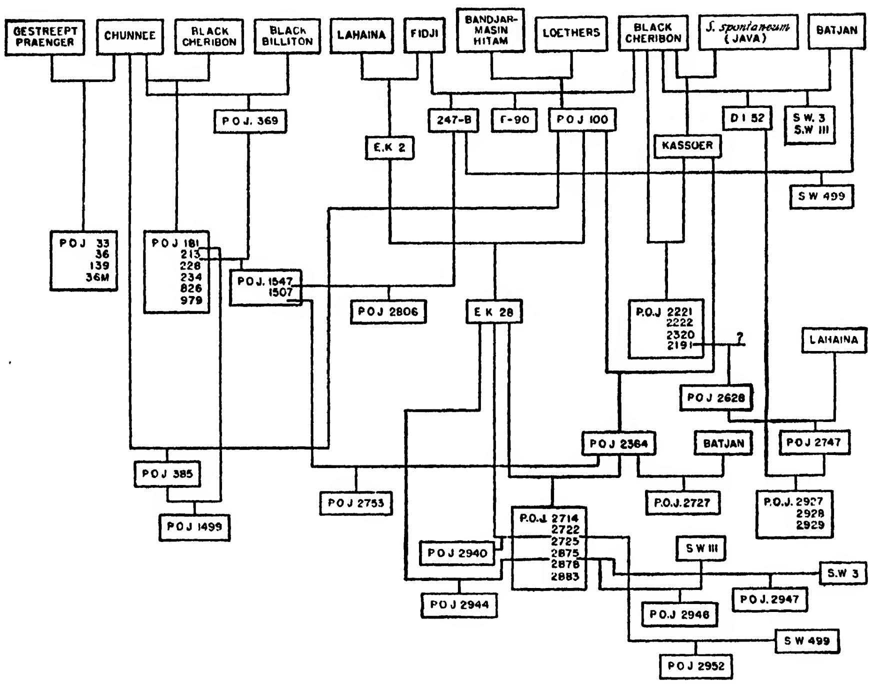

FIGURE 12.—Parentage of Java (P. O. J., Proefstation Oost Java) hybrid sugarcanes.

and greater resistance to disease. The seedlings, however, were very disappointing in habit of growth and sugar content, and all of them were discarded.

During this time (1886–1911) commercial varieties were produced by crossing noble varieties. The outstanding noble hybrids were P. O. J. 100, 247–B, D. I. 52, E. K. 2, and E. K. 28. These hybrids were not only of commercial value but also important parents in the subsequent breeding program.

[11] Many varieties of sugarcane bred at experiment stations are designated by letters or other abbreviations, usually indicating the place or institution where they originated. The meanings of such designations for varieties mentioned in this article are as follows: P. O. J.=Proefstation Oost Java; Co.=Coimbatore (India); C. P.=Canal Point (Fla.); E. K.=Edward Karthaus, S. W.=Sempal Wadak; D. I.=Dimak Idjoe; S. C.=Saint Croix; B.=Barbados; Ba.=Barbados selfed; B. H.=Barbados hybrid; D.=Demerara; H=Hawaii; M.=Mauritius; R.=Reunion; F. C.=Fajardo Central; P. S. A.=Philippine Sugar Association; S. J.=South Johnston; Q.=Queensland.

In 1910 Wilbrink crossed the noble varieties, Gestreept Praenger, Black Cheribon, and P. O. J. 100, with Kassoer. The progenies were not of commercial value, but they furnished the breeding stock which was used by Jeswiet to produce the very high yielding, disease-resistant varieties, P. O. J. 2714, P. O. J. 2725, P. O. J. 2878, etc.

The important step in the production of these varieties was the back-crossing to noble varieties. This process has been called nobilization. Thus, if Kassoer is a hybrid of *S. officinarum* (a noble cane)$\times$*S. spontaneum*, it is a seedling of the first nobilization. The cross of the F_1, or Kassoer in this case, to a noble cane (P. O. J. 100$\times$ Kassoer) gives seedlings of the second nobilization, P. O. J. 2364. The cross of the seedlings of the second nobilization to a noble cane (P. O. J. 2364$\times$E. K. 28) gives seedlings of the third nobilization, P. O. J. 2725, P. O. J. 2878.

The parentage of the important hybrids is given in figure 12.

The diagram shows that the noble parents were for the most part varieties formerly of high commercial value—Black Cheribon, P. O. J. 100, E. K. 28, D. I. 52, S. W. 3, S. W. 111, S. W. 499. The other parents, Kassoer and P. O. J. 2364, have good agronomic characteristics, but they are of no direct commercial value because of their low yields of sugar. It appears, therefore, that varieties which prove to be of value as parents possess themselves some qualities which distinguish them from the bulk of the varieties.

It is also important to note that while the breeding program is essentially a nobilization of Kassoer, the supposed original parent, Black Cheribon, is not used, but the dilution of *S. spontaneum* blood is by means of crosses to other noble varieties. Thus the crosses are back crosses only in a very broad sense.

This method of breeding has produced several commercial varieties. Unquestionably, P. O. J. 2878 is the most important. It is immune or resistant to the major sugarcane diseases, and its yield of sugar per unit area is much greater than that of any variety ever grown in Java. Although it is a commercial cane in other countries, it is preeminently adapted to the country for which it was produced.

BREEDING WORK AT THE BARBADOS STATION (1887)

Sugarcane breeding was begun in Barbados almost simultaneously with the work in Java. Until recent years all the seedlings were from selfs or crosses of varieties of *S. officinarum* (*12*). This is the most extended breeding program within a single species of sugarcane. Prior to 1902 the parents were not known, and for the whole period, 1887–1925, seedlings were from chance-pollinated varieties, supplemented by seedlings from controlled pollination. The result of this program was the development of five distinct lines of noble varieties of different descent.

Two of the lines are descended from White Transparent. The original parent or parents of the other lines are not known, but it is very probable that these lines were derived from a very few noble varieties.

Varieties in each line have characteristics in common and are the nearest approach to "pure" lines obtained in sugarcane. Crosses

between varieties from different lines produce better seedling populations than crosses between varieties of the same line. Thus there is some indication at least that the lines are tending to become homozygous or pure for certain characters.

The seedlings obtained from these crosses are well suited to conditions in Barbados and a greater part of the West Indies. In general, the varieties are excellent from the standpoint of milling and juice quality, because the fiber content is low and the percentage of sucrose in the juice is high. The relatively infrequent flowering is a highly advantageous feature under conditions where considerable vegetative growth may still be made during and after the flowering season if the plants have not flowered. The varieties yield a relatively good tonnage of cane on a wide range of soil types and are easily cut and transported. They have produced types which yield rather well under an annual rainfall of slightly less than 40 inches.

These varieties have several defects. Germination and establishment of a crop is not as good as with the Javanese and Indian varieties. They are susceptible to drying and rotting after being cut. The canes on aging offer little resistance to the attack of weak parasitic or saprophytic fungi. They are all susceptible to mosaic, which limits the area in which they can be planted.

The most important seedlings produced in Barbados are B. H. 10/12 and S. C. 12/4, but many other seedlings have been and are grown commercially.

When it is considered that only a few noble varieties were used to produce these excellent seedlings, and that other stations have produced highly productive varieties from a few noble parents, it is evident that the full amplitude of variation of *S. officinarum* has not been utilized. A wide range of crosses within the species might produce additional commercial varieties and without a doubt would produce valuable breeding material.

At the present time the Barbados station is crossing Barbados varieties with outstanding noble varieties produced at other stations, and is also using these varieties in interspecific crosses in a nobilization-breeding program similar to that employed in Java.

BREEDING WORK AT THE COIMBATORE STATION (1912)

In British India sugarcane is grown over a large area where soil and climatic conditions are not favorable for varieties of *S. officinarum*. The hardy indigenous varieties are adapted to these conditions, but their yield of sugar is very low. The problem of the breeder at Coimbatore, India, is to produce high-yielding varieties adapted to these conditions (*17*).

During the first few years of breeding at Coimbatore a Javanese variety, P. O. J. 213, was largely used as a female parent. It had to be given up, however, because of the susceptibility of its seedlings to mosaic, red rot, and smut. In recent years most of the parents employed are of Coimbatore origin.

Coimbatore was the first station to deliberately use *S. spontaneum* (India) in crosses with *S. officinarum* (1912). It is remarkable that a commercial seedling, Co. 205, was obtained from the first generation.

Co. 205 (*18*) has a fair sugar yield and is susceptible to mosaic. Its behavior is in marked contrast to the behavior of the F_1 seedlings of *S. officinarum* × *S. spontaneum* (Java), which have a low sugar content and are immune to mosaic.

The parentage of the Coimbatore seedlings and the essential features of the breeding program are shown in figure 13.

Several of the important seedlings, Co. 281, Co. 290, Co. 221, are hybrids of three species of sugarcane, *S. officinarum*, *S. spontaneum*, and *S. barberi*. These trihybrid varieties are particularly well adapted to culture in subtropical regions. They are commercial canes in India, Australia, Louisiana, Natal, Argentina, Brazil, and on the poorer soils of the Tropics.

The Coimbatore station is also breeding canes for the tropical portions of India. In this program noble varieties, Coimbatore hybrids, Kassoer, and Javanese hybrids are the type of parents used. It is essentially a nobilization program, the purpose of which is to produce thick-stalked varieties especially adapted to tropical India.

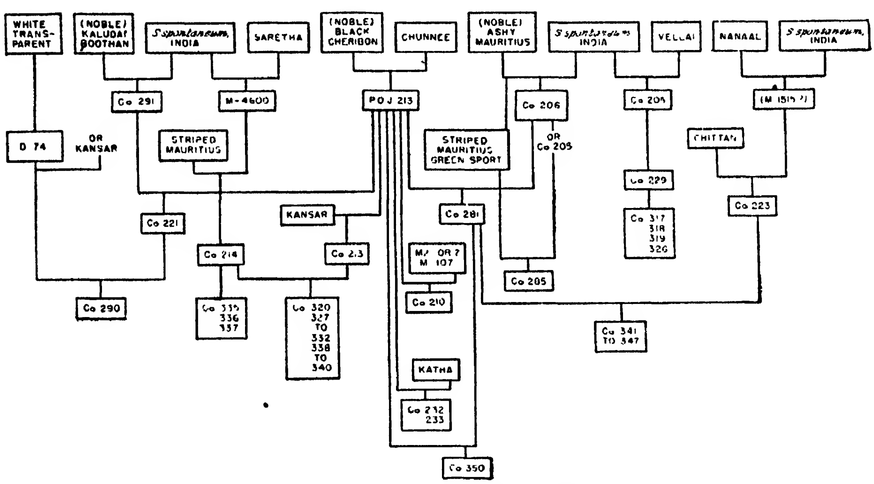

FIGURE 13.—Parentage of Coimbatore sugarcane seedlings. Many of the parents are putative.

BREEDING WORK AT THE CANAL POINT STATION (1918)

Canal Point, Fla., is one of the few places outside the Tropics where sugarcane flowers. While the number of varieties that flower is not so great as in the more favorably located tropical stations, it is sufficient for carrying on a rather extensive breeding program.

During the first 10 years the breeding work was dominated by economic considerations and the need to produce quickly a new cane to replace the old noble varieties D-74 and Louisiana Purple, which had failed largely because they were susceptible to mosaic, root rot, and red rot (fig. 14). During this period the station produced C. P. 807, C. P. 28/11, and C. P. 28/19, disease-resistant varieties adapted to the soil and climate of the sugarcane areas of the United States. These three varieties and two importations, Co. 281 and Co. 290, are now

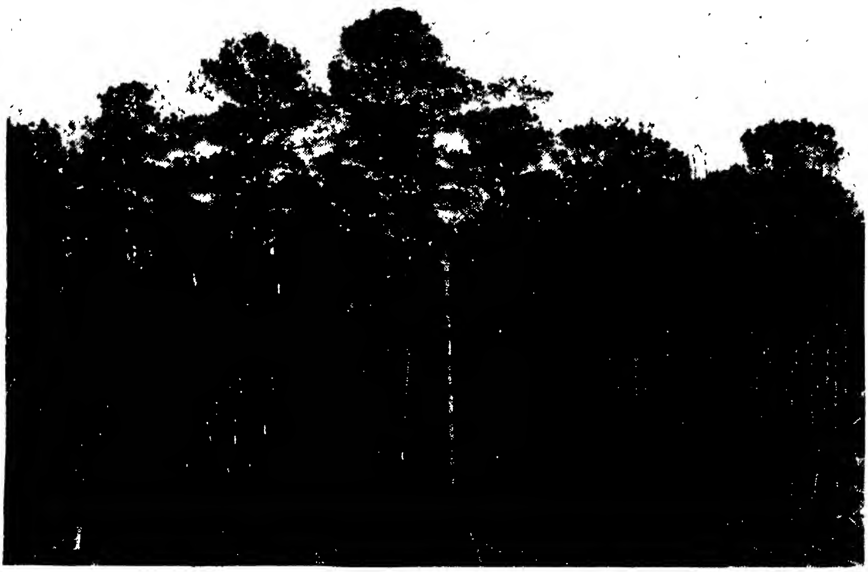

FIGURE 14.

Resistance to mosaic by breeding: *A*, The two middle rows are of a variety formerly grown in Louisiana but completely eliminated because of extreme injury by mosaic. The two end rows at the left are of a variety obtained by crossing the variety in the middle rows with a variety from India somewhat resistant to mosaic. The two end rows at the right represent results of crossing the hybrid thus obtained with another hybrid having one-half of the blood of the wild cane *Saccharum spontaneum*, which is immune to mosaic.

the standard canes, and under field conditions they have proved a great advance on the old varieties formerly cultivated.

All of these varieties were products of a hit-or-miss method, which is the common method at all sugarcane-breeding stations. Beginning with 1928, however, a definite system of crosses was initiated with the purpose of building up breeding stocks of known constitution. Essentially, this is a program of crossing, back-crossing, and selfing, accompanied by selection, in an effort to improve varieties of sugarcane without interfering with their behavior in hybrid combination. The plan is intended to accomplish this by combining the favorable factors from two or more varieties into a single variety. Figures 6–10, previously noted, illustrate this process.

The success of the program depends upon the selection of parents of proven value. By evaluating the progenies produced in former years, it was possible to select four combinations which gave seedlings approaching the desired type. Following the selection of parents, the essential steps in the breeding program are:

(1) Two varieties, *A* and *B*, possessing the desirable agronomic characters—some characters in *A* and some in *B*—are crossed.

(2) Selected F_1 seedlings are back-crossed to one parent *A*, to recover or intensify the important characters of that variety. Seedlings retained from this cross are those that have the essential factors from *B*, which was not used in the back-cross.

(3) At the same time the best pollen-fertile seedlings are used to start selfed lines, from which the individuals that approach the desired type are selected. This inbreeding is an attempt to fix the added characters so that they will breed true.

FIGURE 14.

B, Comparative yields obtained from the three varieties illustrated in *A*. Mosaic was rampant in this field when the picture was taken.

(4) These operations are performed with each of the original varieties as the parent used for back-crossing. It is important to note, however, that the same F_1 seedling cannot be back-crossed to both parents, because emasculation of the parent with fertile pollen (the male) is not practicable. Therefore, selected male F_1 seedlings are back-crossed to the female parent and selected female F_1 seedlings are back-crossed to the male parent.

(5) Further improvement will be obtained by repeating the operations, using the recovered varieties (selected seedlings from the third or fourth back-cross) in place of the original varieties as foundation stock and introducing new factors by crossing recovered varieties from other lines.

The method is slow, since it takes 5 or 6 years to make four or five back-crosses, yet it affords the same opportunities for the production of new commercial varieties as a system based on chance alone, and at the same time it furnishes a means of building up breeding stock of known potentialities.

Since parents used in the breeding program are species hybrids, the behavior of the chromosomes with respect to deviation in number (see section on chromosome behavior p. 597) will have an important bearing on the result. Fortunately, the commercial propagation of sugarcane is by cuttings; therefore, any useful variety produced by chromosomal aberration may be readily propagated and exploited.

The review of the work at the stations in Java, Barbados, India, and Florida gives a general idea of the methods used in breeding new varieties of sugarcane. The breeding at other stations does not differ in any essential feature. Summing up briefly, the most impor-

tant results have been obtained from (1) crosses of *S. officinarum* × *S. spontaneum* and subsequent nobilizations; (2) the crosses of *S. officinarum*, *S. spontaneum*, and *S. barberi*; and (3) varietal crosses within the species *S. officinarum*. While important seedlings have been produced by crosses between varieties of the same species, the crosses between species are of much greater economic importance. These crosses have produced disease-resistant varieties that have increased the yield per unit area by several fold and are adapted to a wide range of soils and climatic conditions.

It is important to note that the brilliant achievements of the past are the result of methods that depended largely on chance. This is not due entirely to lack of a breeding program, but rather to the capricious nature of the sugarcane plant, which makes it very difficult to follow a definite plan.

Aside from the production of improved commercial varieties, the trial-and-error method has produced a large amount of breeding material, so that it is now possible to carry on a program with a view to determining the inheritance of the more important characters. But until something more is known about the genetics of sugarcane, the best combinations will be found by a trial-and-error method in the hands of an intelligent and industrious breeder who makes a large number of crosses and observes the progenies under the particular conditions for which he is attempting to produce a new variety.

Crosses Between Sugarcane and Other Genera

Perhaps the most outstanding intergeneric hybrids among plant crops are those that have come from the maize-teosinte, wheat-rye, and sugarcane-sorghum crosses. Sugarcane has also been crossed with species of the closely related genus *Erianthus*. The crosses of *S. officinarum* with *Erianthus* have not produced any commercial types of canes (*15*). The F_1 seedlings resemble sugarcane more than they do *Erianthus*, but they definitely possess *Erianthus* characters. Most of these hybrids are pollen-sterile, but a few have from 10 to 30 percent of good pollen, so that it will be possible to carry on further breeding. At present very little is known of the commercial value of these interesting hybrids.

The cross of sugarcane-sorghum holds greater commercial promise. The purpose of the cross was to produce a variety of sugar plant that would mature in about 6 months. It would be especially valuable in the sub-Tropics, because such a variety would increase the number of working days in a factory, obviously a factor in lowering the cost of production. There is also the possibility of extending sugarcane production into the temperate zones.

The first sugarcane-sorghum cross was made by Thomas and Venkatraman (*16*) at Coimbatore, India. They crossed the sugarcane P. O. J. 2725 and *Sorghum durra*, Stapf, a grain sorghum. This cross has been repeated at the United States Sugar Plant Field Station, Canal Point, Fla., and in addition several crosses have been made between P. O. J. 2725 and other sugarcane varieties and varieties of sorgo.[12] The hybrids include many albinos, which die in the seedling stage. Of the remainder, a large number are abnormal and develop into obviously uneconomical types. Fortunately, there are quite a number of hybrids that grow like sugarcane and have a good sugar content. Thus far, however, early maturing commercial types have

[12] Sorgo=sweet sorghum.

not been produced. The progress made in a few years is encouraging, and hybridization of sugarcane with other genera seems to be justified. It will require several years of breeding to determine the practical possibilities of this method.

The Slow Process of Progeny Testing

The possibility of crossing different species and genera is most attractive to plant breeders and agronomists, since by this means the most useful characters of two or more species may be combined in a single variety. Most plant breeders have been skeptical of applying the method, especially to plants reproduced by seed. The results with sugarcane, which is vegetatively propagated, lead to greater optimism, since there were no outstanding disease-resistant varieties produced until species crosses were resorted to. Practically nothing, however, is known about the inheritance of characters in the highly polyploid species of *Saccharum*.[13] An added difficulty is that the majority of economically significant characters are quantitative. In the past, quantitative characters have been neglected because of their complicated nature and the existence of so many intermediate forms. Even for simple diploid plants, about which most is known genetically, there are only fragmentary data on the inheritance of quantitative characters. In dealing with such a complex problem, the scale on which the work is carried out is of extreme importance. In order to find valuable forms combining the useful characters of the parents, it is essential to produce large progenies for several generations.

It is evident that for successful breeding of heterozygous polyploid plants, it is necessary to have a method for the accurate determination of the breeding value of parent varieties. The progeny test, which consists essentially in determining the number and proportion of the various kinds of seedlings produced by an individual or cross, provides the most reliable method of evaluating the breeding potentialities of the parents.

This method is used at Canal Point to determine the breeding value of the parents in the different crosses. Large progenies of the best crosses are sent to the major sugarcane districts of the United States and tested for their adaptability to the conditions in each district. It is essential that the progeny test be conducted under the environmental conditions in which the variety presumably will be grown, so that they may be subjected to the disease, soil, and climatic factors that will determine the success or failure of the new production.

The essential features of the method used for testing the progeny and selecting new varieties, which is long and painstaking, will be outlined briefly.

Two varieties that possess the essential characters between them are crossed, and if the resulting individuals approach the desired types, they and subsequent progenies are sent to the district for which the new variety is intended. Finding a productive combination may take from 1 to several years. Let us suppose that the progeny is to be tested in Louisiana. It is necessary to segregate those varieties that are adapted to the soil and climatic conditions of Louisiana. The individuals selected must be vigorous and early maturing, have

[13] See the later section on chromosome behavior, p. 597.

good keeping qualities in the windrow, and be resistant or immune to mosaic and red rot.

During the first year every individual of the progeny is inoculated with mosaic. This is done because under natural conditions the disease fluctuates between wide limits in its spread, and a susceptible variety may escape infection for several years. If the plants are artificially inoculated, it is possible to segregate the susceptible and immune varieties during the first year.

Beginning early in the autumn, the sucrose content of all the individuals that approach commercial types is determined. Those that have a satisfactory sugar content and early maturity are segregated from the rest. These seedlings are now inoculated with different strains of red rot (*Colletotrichum falcatum*), and only those that are resistant to the extent required commercially are retained and planted in increase plots on different soil types.

The next year the seedlings are given the same treatment, and the original planting is observed to determine the stubbling qualities of the selected individuals. The varieties that continue to show promise are sent to various places throughout the State to be increased; or, if the supply of cuttings is ample, they are planted in replicated variety tests.

In these tests the yielding capacity of the new variety is compared with that of the standard commercial varieties for at least 3 years. If the new variety is superior, it is released for commercial culture. It usually takes from 5 to 6 years to test a new variety. Before it is released, it is necessary to determine the yielding capacity per unit area, resistance to the major diseases, and the soil type to which it is best adapted. The data collected are a further contribution to our knowledge of the inherent characteristics of the parents.

The improvement of varieties by hybridization and progeny testing has many ramifications. It is a vast field in which the efforts of the agronomist, cytologist, plant pathologist, and plant breeder are combined.

Theoretical and Practical Progress Go Hand in Hand

Throughout the long history of sugarcane culture there has been a continuous procession of varieties. A variety attained commercial prominence and was successful for a varying period of years. Owing to a change in conditions, diminishing soil fertility, or the incidence of disease, the variety failed. It was then replaced by a new and superior variety. There seems to be no end to this process. The ideal sugarcane, with its characteristics, is but vaguely formulated and reformed after each advance. It must be remembered that the sugarcane plant is a living, dynamic thing that can be molded into an almost infinite number of forms. Each advance, trivial though it may be in relation to the ultimate goal, is a reward and an incentive to continued endeavor.

From the theoretical standpoint, our knowledge of *Saccharum* is very fragmentary. It is essential for further improvement that a world collection of all the cultivated and wild species of sugarcane and closely related grasses be made. For more than 15 years the United States Department of Agriculture has been assembling cultivated and wild varieties of sugarcane from all over the world. Emphasis is placed on the areas where the plant is presumed to be

indigenous, and collections have been made in southeastern Asia and islands of the Pacific, including Taiwan, the Philippines, New Guinea, the New Hebrides, New Caledonia, and the Loyalty, Fiji, Tonga, Samoa, Cook, Hawaiian, and Society Islands.

The area is vast, communication is difficult, and progress is slow, but in four expeditions during the 15 years several hundred varieties have been collected and more than half of them have been safely established in the United States. The material that is now available and that which will be obtained will make it possible to place the whole problem on a new footing. Then by breeding within the species, choosing the extreme types as parents, it will be possible to determine the full amplitude of natural variation within a species and the potentialities for developing new and useful types by species hybridization.

It may appear that all the above is purely theoretical. The important and remarkable feature of modern plant breeding, however, is that the solution of the main theoretical problems is simultaneously leading to the solution of the most urgent problems of practical agriculture.

Chromosome Numbers and Chromosome Behavior in the Sugarcane

WITH few exceptions, the number of chromosomes in the cells of an individual is constant and characteristic of the species to which the individual belongs. Different species may have the same number of chromosomes, but it is needless to point out that they are qualitatively very different. The chromosomes themselves possess a definite individuality. Therefore, the chromosome numbers may be of value in determining whether or not a classification based on morphological character, or form, is correct. They also may offer evidence in efforts to trace the probable ancestors of sugarcane.

Before taking up these questions it may be well to review briefly the normal behavior of the chromosomes in sugarcane. It has been pointed out above that the number of chromosomes in the cells of an individual is constant and characteristic of the species to which it belongs. For example, the varieties of *Saccharum officinarum* have 80 chromosomes in their cells. It is not necessary here to show how this number is kept constant during the growth of the plant by cell division, but merely to state that when a cell is about to divide the chromosomes split lengthwise into two parts that are quantitatively and qualitatively equal, thus forming pairs of chromosomes. The chromosomes of each pair separate from each other, moving to opposite poles of the cell, and a cell wall is formed between the two groups. The division of the cell gives rise to two daughter cells, each of which contains exactly the same number of identical chromosomes. This number is called the somatic, diploid, or 2 n number of chromosomes. When sexual cells are formed, a different set of phenomena occur which results in the reduction of the number of chromosomes to one-half of that characteristic of the somatic or body cells. This is

accomplished by what is known as the reduction division. In this division the chromosomes do not split longitudinally, but each chromosome derived from the male parent pairs or associates homologously throughout its length with its homologue, the like chromosome derived from the female parent. Thus if there were 80 chromosomes to start with, there are now, at the time of the division, 40 double or paired or bivalent chromosomes. The members of each pair then separate and are distributed to opposite poles of the cell. When the cell itself divides, each of the two daughter cells receives one member of each pair of chromosomes, or 40 chromosomes in all. In this way the sexual cells (eggs and pollen) of noble canes receive 40 chromosomes. In the reduction division the segregation of one pair

LACK of resistance to mosaic in varieties of sugarcane formerly grown in Louisiana brought the industry to the brink of ruin a dozen years ago. Production of sugar fell from an average of over 200,000 tons to a low of 47,000 tons a year, and it is estimated that losses to the sugar and sirup industries of the South amounted to $100,000,000. Plant breeders began a world-wide search for resistant varieties and instituted a program of selection and breeding. Results have exceeded expectations. After being forsaken as a business risk by almost all financing institutions, the sugar industry in the South has been restored, and yields per acre are now higher and are obtained at less cost than before the mosaic epidemic. The plant breeder has demonstrated that he can not only meet the challenge of diseases, but turn it to advantage.

of chromosomes is entirely independent of that of any other pair, so that there can be as many different combinations as chance might bring about among 40 different pairs. The reduced number of chromosomes is known as the monoploid (haploid) or *n* number of chromosomes.

Now when an egg that has 40 chromosomes is fertilized by a sperm bearing 40 chromosomes, the resulting zygote will develop into a plant with 80 somatic chromosomes. This number, as we have seen, is a constant characteristic of *S. officinarum*.

The study of chromosome number has revealed a phenomenon that occurs rather frequently in plants. It is often found that the number of chromosomes of the species of a genus is a multiple of a constant

or basic number. In wheat (*Triticum*) the basic number is 7, and there are species with 14, 28, and 42 chromosomes. Thus, there are species with two, four, and six sets of 7 chromosomes, and these species are respectively diploid, tetraploid, and hexaploid. In sugarcane the basic number is probably 10, but whether it is a primary or secondary basic number is an open question. The species of *S. officinarum* have, on this assumption, 8 sets of 10 chromosomes. The plant, therefore, is octoploid. All the known species of sugarcane are polyploids, that is, they have several sets of the basic number. The simple diploid forms with 20 somatic chromosomes are unknown.

In diploid plants which have two sets of homologous chromosomes, the segregation of characters follows along rather simple Mendelian lines. In tretaploid and higher polyploid plants, the segregation becomes much more complicated so that it is very difficult to work out the mode of inheritance of a character. Thus, in sugarcane, which is octoploid, if on hybridization the chromosomes of any one set are capable of pairing with their respective homologues of any of the seven other sets, the possible number of different chromosome combinations will be so enormous that a representative progeny could not be raised in a lifetime.

Since all the species of sugarcane are polyploid, the exact nature and segregation of hereditary factors may never be worked out. In addition, all sugarcanes are heterozygous to a high degree, and all individuals resulting from varietal or species crosses are heterozygous. There is, however, considerable knowledge of the behavior of the chromosomes of different lines of descent in hybrid combination.

SEARCHING THE CELLS FOR EVIDENCE OF ANCESTRY

The distribution of the wild forms of sugarcane is partially correlated with chromosome number. In general, the forms with the higher number of chromosomes are confined to the Tropics and the forms with a lower chromosome number extend into the subtropical and temperate zones. Thus, the forms with 112 and 124 somatic chromosomes are found in Java and the islands nearby. The forms with 80 somatic chromosomes extend northward to the Philippines and Taiwan. Intermediate forms with 96 chromosomes are found in the Celebes and Indochina. In British India are forms with 78 and 64 somatic chromosomes. There are exceptions; the Tananggé of North Celebes with 60 somatic chromosomes and *S. robustum* of New Guinea with 82 somatic chromosomes, so far as is known, are confined to the Tropics.

A fact that may be significant, however, is that in British India there are distinct forms of *S. spontaneum* and also distinct groups of cultivated canes that differ remarkably from the cultivated canes of the Tropics. The forms of *S. officinarum* attain their maximum growth in the more essentially tropical areas, while the forms peculiar to British India are adapted to a cooler climate and do not succeed in the Tropics. It appears, therefore, that the cultivated species of sugarcane originated in different places and presumably from different lines of descent.

The chromosome numbers of the existing forms do not give any clews to the descent of the cultivated species. The basic number of *Saccharum* is probably 10. Diploid forms of *Saccharum* with 20

somatic chromosomes, forms that could be considered primitive, are not known. This also applies to the tetraploid forms with 40 somatic chromosomes. They probably are extinct, but it is possible that they may still exist. The simplest forms known are the Tananggé cane of the Celebes, a hexaploid with 60 somatic chromosomes, and the octoploid forms of *S. officinarum* and *S. spontaneum* Tabongo. Most of the other known forms of *Saccharum* have chromosome numbers that are not a multiple of 10, but are aneuploids. Thus, the British Indian canes have 82, 91, 107, 116, 124. Forms of *S. spontaneum* have 64, 78, 96, 112, 124. *S. robustum* has 84 chromosomes. All the known

THROUGHOUT the long history of sugarcane culture there has been a continuous procession of varieties. A variety attained commercial prominence, was successful for a few years, then failed because of changed conditions, diminishing soil fertility, or disease—to be replaced by something new and superior. There seems to be no end to this process. It must be remembered that the sugarcane plant is a living, dynamic thing that can be molded into an almost infinite number of forms. It is essential for further improvement that a world collection be made of all cultivated and wild species and closely related grasses. For more than 15 years the Department of Agriculture has been making such a collection. With such material available, the problem is placed on a new footing, since it will be possible to determine the full range of natural variation within a species and the possibilities for developing useful new types by hybridization.

species of *Saccharum* are complex polyploids or aneuploids. Chromosome balance is very important in developing new species.

The main course of evolution appears to have proceeded by changes in the number and qualities of the chromosomes, natural selection preserving the changes that have a positive survival value. With the passage of time a given species may acquire a different genetic constitution, owing to the accumulation of mutations. By this means variation within a species may give rise to specific forms which, when crossed, give only sterile hybrids because of the differentiation of the chromosome sets and consequent failure of pairing in the hybrid. Thus species which have descended from a common ancestor and still

have many characters in common will produce sterile hybrids because the chromosomes are too different to pair.

These hybrids can survive sexually if doubling of the chromosome number occurs, for then each chromosome has an identical mate. The chromosomes pair normally and fertile germ cells are formed.

In the genus *Saccharum* there are several species and many varieties, all of which give fertile hybrids. In most of the species crosses there is a doubling of the chromosome number of one parent. So long as it does not disturb the normal proportion of elements, a change in the number of chromosomes—as in the hybrids of *S. officinarum*×*S. spontaneum* where the entire set of the noble chromosomes is doubled—does not greatly alter morphological characteristics, but does tend to increase size and yielding capacity with ascending multiples of the monoploid number. While doubling of chromosomes in the hybrids of diploid plants produces distinct types, it appears that the highly polyploid forms of sugarcane are probably of little importance in the evolution of new forms or species.

Changes that disturb the chromosome balance, however, are of primary importance in evolution. For instance, the loss of a single chromosome, leaving some specific chromosome without a homologue, disturbs the genetic balance in its entirety. This alters the interrelationship of the chromosomes, and the factor balance previously associated with the normal phenotype, and thus produces a general morphological change. The loss of a single chromosome usually causes a greater morphological change than the duplication of an entire set.

It is quite apparent that in highly polyploid plants like sugarcane, which have several sets of homologous chromosomes, a slight change in chromosome number probably would not disturb the balance or produce an appreciable morphological change.

It seems very improbable that the cultivated forms of *S. officinarum* could have originated from hybridization between species of the existing complex wild forms, followed by a doubling of the chromosome number, because the cultivated species have a rather low chromosome number comparatively speaking. The large difference in chromosome number makes it just as improbable that they could have arisen through chromosome aberration, either by the elimination of chromosomes in the somatic division or by the formation of aberrant gametes.

The doubling of the chromosomes of *S. officinarum* in crosses with the other species of *Saccharum* indicates a different line of descent. Since most of the other possible species crosses have not been studied, the chromosome behavior is not known, except for the cross of a British Indian variety, Saretha×*S. spontaneum* Coimbatore. In this cross there was no doubling of chromosomes, which may indicate a relationship between the Indian cultivated varieties and the Indian forms of *S. spontaneum*. Even in this case, however, the chromosomes from the different species may have paired among themselves.

The incidence of mosaic disease in the species and species crosses gives information that may be of value in tracing descent. All the species of *S. spontaneum* except *S. spontaneum* Koelawi A are immune, while all the varieties of *S. officinarum* and all the cultivated forms of British India are susceptible. The hybrids of *S. officinarum* and the forms of *S. spontaneum* with 112 and 80 somatic chromosomes are immune, while hybrids of noble varieties and *S. spontaneum* forms of

India are susceptible. It seems from this point of view that the Indian cultivated canes are more closely related to the Indian *spontaneum* than the noble canes are to the tropical varieties of *S. spontaneum*. The only other known wild species, *S. robustum*, is susceptible to mosaic. Some of its morphological characters are similar to those of *S. officinarum*, and the behavior of the chromosomes of these species in hybrid combination indicates that many of their chromosomes may be homologous. It appears, therefore, that *S. officinarum* and *S. robustum* are rather closely related and probably are from the same line of descent.

Experimental breeding with sugarcane species and closely related grasses may shed more light on the origin of the cultivated sugarcanes. For the present it seems that the most plausible theory of the origin of the cultivated species is that besides *S. spontaneum* and *S. robustum*, other species of *Saccharum*, which are unknown or perhaps extinct, have also contributed to the formation of these species.

THE RELATION OF CHROMOSOME NUMBERS TO BOTANICAL CLASSIFICATION

The chromosome numbers of the species of *Saccharum* as at present classified, and of two closely related genera of grasses, are given in table 2.

TABLE 2.—*Diploid chromosome number of species of Saccharum and related grasses* [1]

Species	Group [2]	Variety	Chromosome
			Number
S. officinarum			80
		Creole [3]	81
		Loethers	98-90
		P. O. J. 100	88-90
		Uba Marot	113
		Naz Reunion	109-110
		Kara Kara Wa	124-126
S. sinense			118
		Kavangire	118
	Pansahi	Uba	116-118
		Cayana	116-118
S. barberi	Sunnabile		116
		Dhaulu	82
	Mungo		82
	Nagori		124
	Saretha		90-92
S. spontaneum	Pasoeroean and other forms of Java, Sumatra, and Borneo.		112
	Tabongo, Paloe, Talahib of northern and central Celebes and the Philippines, respectively.		80
	Biroh of central Celebes and forms from Mandalay, Burma.		96
		Glagah Krakatau	124
	Tananggé of northern Celebes and Teboe Salah of Borneo.		60
		Sumatra (thin-stemmed)	108
		Sumatra (thick-stemmed)	128
	Coimbatore and Rellegaddi, India		64
		Dacca, India	78
		Dehra dun, India	54
S. robustum			84
S. biflorum			112
S. narenga			30
Erianthus arundinaceus			60
		Coimbatore form	40
E. sara			60
E. elegans			40
E. ravennae			20
Sorghum			20
Miscanthus japonicus			38

[1] The chromosome counts are for the most part by G. Bremer.
[2] The groups are for convenience and do not necessarily represent botanical classifications.
[3] The varieties here listed under *S. officinarum* are examples of the numerous varieties assigned to that species because of morphological resemblance but with chromosome numbers that depart from the number 40 usually found. Probably they are hybrids.

In the morphological classification of the species there are sufficient distinguishing characteristics between *S. officinarum* and *S. spontaneum*, but there seems to be a lack of good criteria on which to base the separation of *S. sinense* and *S. barberi*, though they are different enough in appearance and cultural characteristics.

Investigations of the chromosome numbers show that *S. officinarum* is a species the varieties of which form a homologous group (*5*). Study of many noble varieties shows that the somatic chromosome number of the group is 80. There are a few varieties, however—Loethers, Creole, Naz Reunion, etc.—that differ somewhat in morphological characters and chromosome number. These forms probably are hybrids between noble varieties and some unknown variety, and as a result of repeated back-crossing to noble canes they have retained only a few of the characters of the nonrecurrent parents.

There is a large number of varieties in *S. sinense*, but the chromosome numbers of only a few have been determined. All that can be said about them at present is that they seem to form a homologous group difficult to define, and that the somatic chromosome number of the few varieties that have been investigated is about 116-118.

Barber (*2*, *3*) has made the most detailed studies of the indigenous sugarcanes of British India. He divided them, according to their external characters, into five groups—Sunnabile, Mungo, Nagori, Saretha, and Pansahi. Jeswiet identified the Pansahi group with *S. sinense*. In this group there are a number of varieties that do not occur exclusively in British India, but are found also in Indochina, South China, and Taiwan. The cane varieties that are native to British India belong to the first four groups, and these have been classified by Jesweit under the name *S. barberi*.

With few exceptions the chromosome numbers corroborate Barber's classification (*6*, *7*, *8*). Each group has a distinctive chromosome number. The varieties of the Sunnabile group have 116–118 chromosomes. This number, however, does not occur in the Dhaulu subgroup, which Barber places under Sunnabile. On the other hand, the canes of the Dhaulu subgroup have the same chromosome number, 82, as the canes of the Mungo group. The Dhaulu varieties differ in a pronounced way from the canes in the Sunnabile group, though they also differ markedly from the varieties of the Mungo group. It seems desirable, therefore, to separate the Dhaulu varieties from the Sunnabile group and to make them a separate group closely related to the Mungo varieties.

It is remarkable that in the canes of the Nagori group, which resemble one another very much, there are two chromosome numbers, 124 and 107. Possibly the original number was 124 and the number 107 was derived from this by chromosome aberration or hybridization. This is merely an attractive supposition.

The chromosome numbers of the varieties of the Saretha group vary from 90 to 92. It might be possible that the forms having 91 chromosomes are hybrids between the forms having 90 and 92 chromosomes.

The list in table 2 includes only the British Indian varieties that have been investigated cytologically. A great many varieties are not represented. Some of these are varieties that Barber was not able to place in the present groups, and many are varieties that were classified but not available for cytological study. It must be remembered, too, that Barber divided the Saretha group and the Sun-

nabile group into two distinct sections according to the geographical distribution of the varieties. The earlier maturing and profusely branching forms occur near the Himalayas, while the late-maturing varieties are found in the peninsula.

From this brief review of the British Indian canes it is evident that grouping them under a species name, *S. barberi*, is rather arbitrary. Pending further investigation, it will be better to retain the separate groups of Barber.

Within the species *S. spontaneum* are forms that differ in external appearance and chromosome number. Table 2 shows that these forms have distinctive chromosome numbers, and that each form has a rather definite geographical distribution. In British India the form Dacca has 78, and the Coimbatore form has 64 somatic chromosomes. In the Philippine Islands, Taiwan, and northern and central Celebes are forms with 80 somatic chromosomes. The forms from Burma and central Celebes have 96 chromosomes. In north Celebes there is also the Tananggé cane with 60 somatic chromosomes. The forms of Java have 112 somatic chromosomes. This number is also found in many clones from Soembawa, Sumatra, and Borneo. A subspecies, *S. biflorum*, from north Africa, has the somatic number 112. The highest somatic chromosome number, 124, is found in a form from Krakatau, a group of small islands between Java and Sumatra. *S. robustum* from New Guinea, a wild cane which is distinct morphologically from the other wild forms, has 84 somatic chromosomes. A species called *S. narenga*, which may not be a sugarcane, has 30 somatic chromosomes.

This list does not include all the forms that would at present be placed in *S. spontaneum*. It is known that in British India there are at least seven different forms. Collections have only recently been made of wild forms in the Pacific islands to the east and southeast of Java. As knowledge concerning these wild canes increases, it probably will be possible to divide *S. spontaneum* into subspecies.

It may be of interest to note the chromosome numbers of genera closely related to sugarcane. In *Erianthus* there are species with 20, 40, and 60 somatic chromosomes. *Miscanthus japonica* has 38 somatic chromosomes.

The cytological investigations in the genus *Saccharum* are, as has been shown in the preceding paragraphs, an aid to classification. This, however, is merely incidental, because the essential function of the chromosomes is to furnish the mechanism for the distribution of hereditary characters.

BEHAVIOR OF CHROMOSOMES IN SPECIES AND GENERIC CROSSES

When a variety of *S. officinarum* with 40 monoploid chromosomes is crossed with a variety of *S. spontaneum* (Java) with 56, one would expect to find the somatic chromosome number of the F_1 progeny to be 96, the sum of the monoploid numbers of the parents. These individuals, however, have 136 somatic chromosomes. This number is exactly 40 more than the sum of the chromosomes in the sexual cells of the parents. The chromosomes of *S. officinarum* split longitudinally, thus doubling their number and forming pairs of homologous chromosomes, and those of *S. spontaneum* pair among themselves. Therefore the F_1 individuals have 80 noble and 56 wild chromosomes.

Since the chromosomes from the different lines of descent are able to pair among themselves, the reduction division of the F_1 individuals is regular, and generally speaking these individuals are highly fertile. Most of them produce fertile eggs and pollen, and only a few are pollen-sterile. Completely sterile individuals do not occur. This is rather unusual because as a rule species hybrids are sterile, and only occasional exceptions are fertile.

The character of the F_1 individuals is in general intermediate between that of the parents. But though the seedlings resemble one another, there is a good deal of individual variation. Since only the chromosomes of like descent will pair, one would expect the F_1 hybrid to breed true. In fact, the F_2 or second generation individual with few exceptions is very similar to the F_1, and types resembling the parents never occur. Most of the F_2 plants have 136 somatic chromosomes, some have less than 136, and a very few may have one or two more than 136. This is due to the fact that the reduction division is not absolutely regular. There are usually from 4 to 12 chromosomes that do not pair. These univalent chromosomes are distributed at random so that sexual cells are formed with chromosome numbers which deviate slightly from the normal monoploid number, 68.

If now an F_1 is back-crossed to *S. officinarum*, the resulting hybrids will have 148 chromosomes. The sexual cells of the F_1 have 68 chromosomes, and the noble cane has 40. Therefore, the number of chromosomes expected would be 108. In this second nobilization there is again an increase of 40 chromosomes over the expected number. Apparently, these chromosome numbers arise because the chromosomes from the noble parent have doubled, so that the back-cross seedlings have received 80 chromosomes from the noble parent and 68 from the F_1 parent. Probably 40 of the chromosomes from the F_1 parent are noble and 28 are *spontaneum* (wild).

The individuals from this cross are immune to mosaic and sereh. In habit they have the characteristics of both parents. The thickness of the stalk approaches that of the noble parent. They are not of commercial value because the sugar content is still too low. However, the plants have proved to be of great value in further breeding work (P. O. J. 2364, 2354, 2323).

The reduction division of these plants is more irregular than in the case of the first back-cross, or first nobilization. Thus, in P. O. J. 2364 the number of univalent chromosomes fluctuates between 16 and 26. Therefore, the chromosome number of the sexual cells deviates considerably from the expected monoploid number, 74. When P. O. J. 2364 is crossed with noble cane, the number of somatic chromosomes in the seedlings will range from 106 to 120. The number oscillates around an average of 114, which is equal to the sum of the monoploid chromosome number, 74 of P. O. J. 2364 and 40 of the noble cane. Here, then, there is no doubling of the noble chromosomes.

This cross has produced very valuable seedlings that are outstanding commercial canes (P. O. J. 2714, 2725, 2878, 2883). The most important one of this group is P. O. J. 2878. The seedlings are very vigorous and produce a very high yield of sugar per unit area. They are not immune to mosaic and sereh, but they are very resistant, seldom taking the disease, so that they have sufficient resistance for commercial purposes. It is probable that these canes have about 14 wild (*S. spontaneum*) chromosomes.

If the seedlings of the third nobilization are again crossed to noble cane, the resulting progeny will have a fair sugar yield, but they are more susceptible to mosaic and sereh—or at least some of them are. The chromosome number of the seedlings ranges from 94 to 100, which is the sum of the monoploid numbers of the parents. Others have from 120 to 126 chromosomes, which is about 20 to 30 more than the sum of the monoploid numbers of the chromosomes of the parents. These forms have about seven *S. spontaneum* chromosomes. Apparently as the number of *S. spontaneum* chromosomes is reduced, the seedlings become more susceptible to disease. Because of the irregularity of the reduction division and nonconjunction of chromosomes, there is of course no certainty about the number of wild chromosomes in the individuals of the successive back-crosses. It is striking, however, to notice that a decrease in the number of *S. spontaneum* chromosomes goes hand in hand with greater susceptibility to disease, and it is rather certain that the *S. spontaneum* chromosomes carry the factors that determine immunity to mosaic and sereh diseases.

Effects of Successive Back Crosses

It may be well to summarize briefly the behavior of chromosomes in a species cross and the successive back-crosses. In crossing *S. officinarum* with *S. spontaneum* Java, the diploid number of chromosomes of the hybrid is not equal to the sum of the monoploid numbers of the parents, but the somatic chromosome number of the hybrid, 136, is due to the doubling of the monoploid chromosomes (40×2) of the noble cane together with the 56 chromosomes of the wild cane. In back-crossing the hybrids to *S. offiicinarum*, the resulting individuals possess 148 somatic chromosomes. Here there is again a doubling of the chromosomes of the noble variety. The number 148 is the sum of twice the monoploid number (40×2) of *S. officinarum* and the haploid chromosome number, 68, of the F_1 hybrid. When the seedlings of the third nobilization are back-crossed to noble cane, there is no doubling of chromosomes. The seedlings of the third and fourth back-cross have a chromosome number that corresponds with the sum of the monoploid chromosomes of the parents, or a slightly larger number.

In the discussion thus far, crosses in which noble canes were used as females have been used to illustrate the behavior of chromosomes in species hybrids. The reciprocal crosses have not been made very often because the F_1 hybrids are very rarely completely pollen sterile. When a pollen sterile individual is found, it can be used as a female in a cross with *S. spontaneum*. The plants resulting from such a cross strongly resemble *S. spontaneum*, forming long stolons, just as *S. spontaneum* does. Stolons do not occur in *S. officinarum* or in the F_1 plants from crosses of *S. officinarum* $\times$ *S. spontaneum*. The F_1 female has about 68 monoploid chromosomes and the male *S. spontaneum* has 56. The seedlings from this cross have 123 or 124 somatic chromosomes. The number equals the sum of the monoploid numbers of the parents. Therefore, when an F_1 individual of *S. officinarum* $\times$ *S. spontaneum* is back-crossed to *S. spontaneum*, doubling of chromosomes does not take place.

Now if a female F_1 is back-crossed to a male noble cane, the individual will have a somatic chromosome number varying from 124 to 138—numbers that are usually larger than the sum of the monoploid

chromosome numbers of the parents, but considerably smaller than the monoploid number of the F_1 plus the diploid number of the noble cane. Thus, the behavior of chromosomes in the crosses (*S. officinarum*$\times$*S. spontaneum*)$\times$*S. spontaneum* and (*S. officinarum*$\times$*S. spontaneum*)$\times$*S. officinarum* is quite different from the behavior in the reciprocal crosses, where there is a doubling of *S. officinarum* chromosomes.

Hybrids with Larger Chromosome Numbers

Hybrids with a somatic chromosome number greater than 148 have been produced. If one of the seedlings of the third nobilization, that is, P. O. J. 2725, with 108 somatic chromosomes, is crossed with *S. spontaneum* Java, the individuals of the progeny will have about 162–164 chromosomes. This number results from the doubling of the monoploid number of P. O. J. 2725 (54×2) together with the monoploid number of *S. spontaneum* (56). These forms are very robust, resembling in general the F_1 plants of *S. officinarum* $\times$ *S. spontaneum*. They are of no commercial value, but no doubt they will be very valuable in further breeding. By back-crossing hybrids of the third and fourth nobilization, it may be possible to produce commercial sugarcanes with higher chromosome numbers, greater vigor, and higher production of sugar.

We have noticed that when *S. officinarum* is crossed with *S. spontaneum* of Java, there is a doubling of the chromosomes of *S. officinarum*. The same thing happens when noble cane is crossed with other forms of *S. spontaneum*, but, of course, the somatic number of chromosomes of the progeny may not be the same. If noble cane is crossed with *S. spontaneum* Tabongo, which has 40 monoploid chromosomes, the progeny will have 120 somatic chromosomes, and if the cross is with *S. spontaneum* of India, with 32 monoploid chromosomes, the progeny will have 112 somatic chromosomes.

It may also be of interest to note the chromosome numbers of individuals derived from a cross of two forms of *S. spontaneum*. *S. spontaneum* Tabongo, with 40 monoploid chromosomes, was crossed with *S. spontaneum* Kepandjen, with 56 monoploid chromosomes. The hybrids have 96 chromosomes. The reduction division is regular, the chromosomes forming 48 pairs. Apparently, the chromosomes from the different lines of descent pair among themselves. The F_1 individuals are fertile, and no doubt they will breed true in subsequent generations because there would be no segregation of characters, and the chromosome number would remain constantly 96.

The F_1 progeny of *S. officinarum* $\times$ *S. spontaneum* Tabongo are immune to mosaic, but some of the F_1 seedlings of *S. officinarum* $\times$ *S. spontaneum* of Coimbatore are susceptible but rather tolerant.

Species Crosses with Saccharum robustum

When *S. officinarum* is crossed with *S. sinense* or *S. barberi*, the monoploid chromosome number of the noble parent is doubled. In the cross *S. barberi* $\times$ *S. spontaneum* of India there is no duplication of chromosomes. When a noble cane is crossed with *S. robustum* there is an increase in chromosomes above the number which corresponds to the sum of the monoploid numbers of the parents, but it is considerably less than the sum of the diploid number of *S. officinarum*

and the monoploid number of *S. robustum*. *S. robustum* is a wild species that breeds true from seed. The sugar content of individuals ranges from 4 to 15 percent, the higher figure approaching that of the noble varieties. The stalks are much larger than those of the *S. spontaneum* forms and its flowers are indistinguishable from those of *S. officinarum*. From a morphological point of view it is much nearer to the noble varieties than are the forms of *S. spontaneum*.

Seedlings from two crosses with noble varieties, D–74 × *S. robustum* and Simpson × *S. robustum*, have been studied cytologically. The seedlings from the cross D–74 × *S. robustum* had 100 somatic chromosomes. The cross Simpson × *S. robustum* produced viable seed; however, in a total of 689 plants, 680 were albinos and only 9 were green. The albino plants died when they were about 2 weeks old, so their chromosome numbers were not determined. The green plants have about 98 chromosomes. The F_1 seedlings are intermediate in character. The diameter of stalks exceeds that of either parent and the length of stalk approaches that of *S. robustum*. The seedlings are susceptible to mosaic.

The behavior of *S. robustum* with noble canes is somewhat similar to that of *S. spontaneum* with noble canes, but the number of chromosomes duplicated is not so large. The monoploid number of chromosomes of the noble varieties is 40 and that of *S. robustum* 42. As noted, the hybrids of D–74 by *S. robustum* have 100 somatic chromosomes, and the green individuals of Simpson × *S. robustum* have 96 to 98 chromosomes instead of 82, which is the sum of the monoploid numbers of the parents. Apparently, there is an increase of 16 to 18 chromosomes. This probably indicates that the noble varieties and *S. robustum* have several homologous chromosomes, or at least chromosomes similar enough to pair, and there is a duplication of a few dissimilar chromosomes of each variety. These duplicated chromosomes from different lines of descent pair among themselves. The chromosome complex of the hybrids may be represented as follows: 32 chromosomes of D–74 pair with 32 homologous chromosomes of *S. robustum;* the remaining 8 chromosomes of D–74 are duplicated and the resulting homologous chromosomes pair among themselves; the remaining 10 chromosomes of *S. robustum* do likewise. $(32 + 32 + (8 \times 2) + (10 \times 2) = 100$.

There is the alternative possiblity that the increase in chromosomes is due to nonconjunction in the reduction division of the parents, resulting in the formation of gametes with deviating chromosome numbers. The reduction division of the parents, however, is regular, so it is very probable that the gametes have the normal monoploid number. Besides, all the F_1 seedlings studied have the same chromosome number, which would not be the case if the increase were due to aberrant gametes. It seems more probable, therefore, that some of the chromosomes of each parent have doubled—but this does not preclude other explanations.

The chromosome number of the hybrids between *S. officinarum* and *S. robustum* is of significance in connection with the chromosome numbers of many original sugarcane varieties from New Guinea. Most of these New Guinea varieties have morphological characteristics like those of *S. officinarum*, but a great many also have some characteristics of *S. robustum*. The chromosome numbers of 152 of these varieties have been determined. When the varieties are grouped according to chromosome number, it is found that 13.16 percent have

about 80 somatic chromosomes, the characteristic number of *S. officinarum*; 70.39 percent have about 100 somatic chromosomes, the same number as the hybrids of *S. officinarum* × *S. robustum*; and 16.45 percent have somatic chromosome numbers from 110 to 149. The morphological characteristics and the chromosome numbers of many original New Guinea varieties indicate rather definitely that they are hybrids of *S. officinarum* × *S. robustum*.

Chromosome Behavior of Generic Hybrids

In the generic cross *S. officinarum* × *Erianthus*, the sugarcane E. K. 28, with 40 monoploid chromosomes, was the female, and *Erianthus sara*, with 30 monoploid chromosomes, was the male parent (*15*). The hybrid plants had 60 to 68 chromosomes, a number which was less than the sum of the monoploid numbers of the parents. The reduction division of E. K. 28 was slightly irregular so there is a possibility that gametes were produced which deviated slightly from the monoploid number 40, in both a positive and a negative direction. The reduction division of *E. sara* is very regular and it is highly probable that all the gametes have 30 chromosomes. Gametes of E. K. 28 with less than the haploid number (30–38) probably have a greater chance to form viable zygotes in combination with gametes of *E. sara* than gametes with exactly the monoploid number or with a slightly larger number. The question why the number of chromosomes of *S. officinarum* was not doubled in the case of these hybrids, while such doubling occurred in the cross of *S. officinarum* and *S. spontaneum*, needs thorough investigation.

The reduction division of the F_1 hybrids is rather irregular, the number of univalent and lagging chromosomes varying from 6 to 14. Therefore, most of the hybrid individuals are pollen-sterile; a minority yield a small percentage of fertile pollen. Nothing is known about the behavior of the chromosomes from the different lines of descent. A correct interpretation of these phenomena will be possible only after continued investigation.

There is only fragmentary knowledge concerning the behavior of the chromosomes of sugarcane-sorghum hybrids. The individuals that have been studied are hybrids of P. O. J. 2725, with 53–54 monoploid chromosomes, and *Sorghum durra*, with 10 monoploid chromosomes. The diploid chromosome numbers of the F_1 seedlings fall into three rather definite groups—64, 74, and 116. The number 64 is the sum of the monoploid numbers of the parents; the number 74 is the sum of the diploid number of sorghum and the monoploid number of sugarcane; and the number 116 arises from the doubling of the sugarcane chromosomes, plus the monoploid number of the sorghum chromosomes. The reduction division of the F_1 individuals is very irregular so that the chromosome counts vary considerably. So far as known, all the hybrids are pollen-sterile, and only a very few fertile eggs are produced. Back-crosses of F_1 individuals to sugarcane have not produced viable seeds. Venkatraman obtained a few plants from the back-cross of an F_1 hybrid to sorghum. One of these back-cross plants has about 74 somatic chromosomes. Since the chromosome number of the F_1 plant used in the cross is not known, it is impossible to postulate the behavior of the chromosomes in the back-cross. Further investigation of these very interesting crosses is being carried on, and no doubt interesting and valuable information will be obtained.

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Appendix

TABLE 3.—*Natural species and some natural varieties of sugarcane*

Species and variety	Sex	Somatic chromosome	Parents	Origin	Important characters	Commercial planting
		Number				
S. officinarum L.		80		Natural	High sucrose; low fiber. Some varieties resistant to gummosis and Fiji disease. Range, tropical.	Most of the varieties of *S. officinarum* formerly were of high commercial value. At present most of the varieties are no longer grown commercially. The few that remain, Crystalina, Yellow Caledonia, Badila, etc., are being replaced by superior hybrid seedlings.
Black Cheribon	Female	80		do		
Gestreept Preanger	do	80		do		
Batjam	Male	80		do		
Bandjarmasin hitam	Female	80		do		
Fiji	do	80		do		
Crystalina	do	80		do		
Otaheite	do	80		do		
Badila	Female and male	80		do		
Yellow Caledonia	Female			do		
Loethers (hybrid?)	Male	98–99		do		
Creole (hybrid?)		81		do		
Naz (Reunion) (hybrid?).		109–110		do		
Uba Marot (hybrid?)	Male	113		do		
Kara Kara Wa (hybrid?).		124–125		do		
S. sinense Roxb.		116–118		do	Great vigor; high fiber; resistant or immune to mosaic; range, tropical and subtropical.	Being replanted by superior seedlings. Still used in Natal, Brazil, and parts of Hawaii.
Kavengirie		118		do		
Uba	Female	116–118		do		
Cayana	do	116–118		do		
S. barberi Jeswiet:						
Sunnabile group		116		do	High fiber; immune to sereh; early maturity; great vigor; subtropical and temperate.	Formerly the commercial canes of India; now largely replaced by superior hybrid varieties.
Dhaulu group		82		do		
Mungo group		82		do		
Nagori group		124		do		
Hybrids		107		do		
Saretha group		90–92		do		
Chunnee group		90–91		do		
S. spontaneum L.	Male			do	Immune to mosaic and sereh; great vigor; high fiber; low sugar content; range, tropical to temperate.	No commercial value.
Pasoeroean and Java forms.	do	112		do		
Tabongo	do	80		do		
Biroh group	do	96		do		
Burma group	do	96		do		
Krakatau	do	124		do		
Tananggé	do	60		do		
Dacca	do	78		do		
Coimbatore	do	64		do		

Sumatra, thin stemmed	do	108		do		
Sumatra, thick stemmed.	do	128		do		
Dehra Dun	do	54		do		
S. robustum (?)	do	84		do	Great vigor; high fiber; range, tropical.	Do.
Self-seedlings		76-84		do	do	Do.
Natural species hybrids:						
Kassoer	Male	136	*S. officinarum* (Black Cheribon) × *S. spontaneum* Java.	do	Immune to mosaic and sereh; high fiber; great vigor.	Do.
Toledo	do	120	*S. officinarum* × *S. spontaneum* Tabongo.	do	do	Do.
Hinds Special	do	120		do	do	Do.

Most of the hybrid seedlings produced the world over are from combinations of the natural varieties and the following hybrids: P. O. J. 100; S. W. 499; E. K. 2, 28; 247B, P. O. J. 2364, 2725, 213, 2878, and 36; Co. 213, 214, 281, and 290; D. 74, 625; Diamond 10; T. 24; S. C. 12/4; B. H. 10/12; Ba. 11569; U. S. 1694; C. P. 1165, 1161; H. Q. 409.

TABLE 4.—*Characteristics of elite breeding stock and commercial seedlings derived from this stock*

Source and variety	Sex	Origin	Parents	Important characters	Commercial plantings: Increasing	Commercial plantings: Decreasing	Commercial plantings: Discontinued	Date bred	Breeder
Africa:									
E-8		Egypt (seed imported from Hawaii).	U. S. 666 selfed	Tolerant to streak disease	(1)			1928	A. J. Mangelsdorf.
M-131	Female	Mauritius		Rapid growth; high sucrose					
R-11	Male	Reunion	P. O. J. 2725 × Uba Marot.	Mosaic resistant; drought resistant; early maturity.	(1)				D. d'Emmerez de Charmoy.
R-54		do	P. O. J. 2725 × D-74	High sucrose; early maturity.	(1)				Do.
R-157		do	P. O. J. 36 × Uba Marot	Resistant to mosaic, gummosis, and rust; high fiber; sugar low; very vigorous.	(1)				Do.
Uba Marot	Male	Natural		Mosaic and drought resistant; vigorous.					
Guingham	Female	do		High sucrose; drought resistant.		×			
Isautier		Reunion	Unknown				×	1889	Dumesgnil.

See footnotes at end of table.

TABLE 4.—*Characteristics of elite breeding stock and commercial seedlings derived from this stock*—Continued

Source and variety	Sex	Origin	Parents	Important characters	Commercial plantings: Increasing	Commercial plantings: Decreasing	Commercial plantings: Discontinued	Date bred	Breeder
Asia:									
Co. 205	Male	India (Coimbatore)	Vellai × *S. spontaneum* India.			×		1914	C. A Barber.
Co. 206	do	do	Ashy Mauritius × *S. spontaneum* India.					1914	Do.
Co. 213	Female	do	P. O. J. 213 × Kansar			×		1914	Do.
Co. 214		do	Striped Mauritius × M 4600.					1914	Do.
Co. 221	Female	do	P. O. J. 213 × Co. 291					1918(?)	T. S. Venkatraman.
Co. 229		do	Co. 205 selfed						Do.
Co. 243		do	A 2 × Co. 206						Do.
Co. 244		do	P. O. J. 213 × Co. 205						Do.
Co. 281	Female	do	P. O. J. 213 × Co. 206		×				Do.
Co. 285		do	Striped Mauritius, Green Sport × Co. 205 (?).	Coimbatore seedlings are in general very vigorous; early maturing; tolerant of mosaic; immune to sereh. Co. 281 resistant to red rot (La.).	×				Do.
Co. 290	Male	do	Co. 221 × D-74(?)		×				Do.
Co. 299		do							Do.
Co. 300		do							Do.
Co. 312	Male	do							Do.
Co. 313	do	do	Co. 213 × Co. 244						Do.
Co. 326		do	Co. 229 selfed						Do.
Co. 331		do	Co. 213 × Co. 214		×				Do.
Co. 347		do	Co. 281 × Co. 223						Do.
Co. 349		do	P. O. J. 2725 × Co. 243						Do.
Co. 350		do	Co. 213 × Co. 281						Do.
Co. 351		do	P. O. J. 2725 × *Sorghum durra*.					1929	Do.
Co. 352		do	do					1929	Do.
Co. 357		do	do					1929	Do.
Co. 402		do	Vellai × Co. 243						Do.
Co. 408		do	P. O. J. 2725 × Co. 243						Do.
Australia and Fiji:									
18 R 1167		Fiji	H 109 × unknown	Resistant to Fiji disease		×		1918	W. A. Speight.
H. Q. 409 (Clark's seedling).		do	87 Couvé × unknown	Resistant to gumming disease.		×		1904	Do.
H. Q. 406		do	Goru × unknown	High quality and tonnage		×		1904	Do.
Broadwater 1		do	Korpi × unknown	Resistant to gummosis		×		1922	D. S. North.
J. S. 2		Queensland	Badila	High quality and vigor but susceptible to mosaic, gumming, and Fiji disease.			×	1922	McWalters.

J. S. 4		do	do	do			×	1922	Do.
J. S. 7		do	do	do			×	1922	Do.
H. Q. 285		do	N. G. 24	Early maturity			×	1905	James Clark.
H. Q. 426		do	do	do			×	1905	Do.
H. Q. 409	Male	do	do	Early maturity, vigor			×	1905	Do.
H. Q. 458		do	do	Disease resistant			×	1905	Do.
Q. 813	Male	do	Badila	do			×	1900	W. Mitchell.
Q. 1098		do	do	do			×	1910	Do.
N. G. 15	Female and male.	Natural		High sucrose					
N. G. 24	Male	do		do					
Oramboo	Female	do		do					
S. J. 684a	do	Queensland		High sucrose, vigor					E. J. Barke.
S. J. 642c	Male	do		Vigor					Do.
S. J. 672b	do	do	Badila × S. C. 12/4	High sucrose, vigor					Do.
S. J. 274a	do	do		Vigor					Do.
S. J. 662b	do	do		do					Do.
S. J. 848a	Female	do		do					Do.
S. J. 267a	Male	do	Rose Bamboo × S. C. 12/4.	do					Do.
Q. 3		do	P. O. J. 2878 × S. J. 86a						
Q. 4		do	P. O. J. 2878 × S. J. 672b						
Q. 5		do	P. O. J. 2364 × S. J. 267a						
Pacific islands:									
Java:									
P. O. J. 36	Female	Java	Gespreept Preanger × Chunnee.	Early maturity, immune to Sereh, mosaic tolerant.	×			1893	J. D. Kobus.
P. O. J. 36-M	do	do	do	do		×		1893	Do.
P. O. J. 105	do	do	do	do		×		1893	Do.
P. O. J. 213	do	do	Black Cheribon × Chunnee.	do		×		1893	Do.
P. O. J. 234	do	do	do	do		×		1893	Do.
P. O. J. 100	do	do	Bandjarmasin hitam × Loethers.	High yield			×	1893	J. H. Wakker.
247 B	Male	do	Black Cheribon × Fiji (?)	do			×	1894	R. J. Bouricius.
E. K. 2	do	do	Lahaina × Fiji	do			×		E. Karthaus.
E. K. 28	do	do	E. K. 2 × P. O. J. 100	do			×	1911	J. W. Versteegh.
D. I. 52	do	do	Black Cheribon × Batjam.	do			×	1903	Stok.
S. W. 3	do	do	do	High yield, early			×		Do.
S. W. 111	do	do	do	do			×		Do.
Tjepiring 24		do	Black Cheribon × Kassoer.	Immune to mosaic and Sereh, great vigor			×	1904	C. J. de Kock.
P. O. J. 2364	Female	do	P. O. J. 100 × Kassoer	do				1911	G. Wilbrink.
P. O. J. 2714	do	do	P. O. J. 2364 × E. K. 28	Resistant to mosaic and Sereh, vigorous.		×		1917	J. Jeswiet.
P. O. J. 2725	do	do	do	do	×			1917	Do.
P. O. J. 2722		do	do	do				1917	Do.
P. O. J. 2878	Male	do	do	Resistant to mosaic and Sereh, high yield.	×			1921	Do.

See footnotes at end of table.

TABLE 4.—*Characteristics of elite breeding stock and commercial seedlings derived from this stock*—Continued

Source and variety	Sex	Origin	Parents	Important characters	Commercial plantings: Increasing	Commercial plantings: Decreasing	Commercial plantings: Discontinued	Date bred	Breeder
Pacific Islands—Contd.									
Hawaii:									
H. 109	Female	Hawaii	Lahaina × unknown	High yield		×		1906	C. F. Echart.
H. 456	Male	do	H. 240		×			1913	Do.
K. 107	do	do	D. 1135 × unknown	Resistant to red stripe and eye spot.	×			1917	W. Twigg-Smith.
K. 202	Female	do	D. 1135 × unknown	do	×			1917	Do.
25 C 14	do	do	Yellow Caledonia × D. 1135.	do				1925	A. J. Mangelsdorf.
25 C 34	Male	do	do	Eyespot resistant				1925	Do.
K. 73	do	do	D. 1135 × unknown	do				1917	W, Twigg-Smith.
H. 9812	do	do						(1930?)	A. J. Mangelsdorf.
U. D. 1		do	Uba × D. 1135	Adapted to poor soils	×			1924	Hawaiian Sugar Planters Association.
McBryde 7		do	Lahaina	Long crops, lower fields	×			1918	McBryde Sugar Co.
Manoa 213		do	Tip	Middle and Makai lands	×			1922	Hawaiian Sugar Planters Association.
Philippines:									
L. C. 25/191 (Aluman).		Philippine Islands	Badila × 247 B	High yield	×			1925	A. Labrador.
P. S. A. 7		do	P. B. 119 × C. A. C. 87	do	×			1925	N. B. Mendiola.
P. S. A. 14		do	do	do	×			1925	Do.
West Indies:									
Barbados:									
B. H. 10/12	Male	Barbados	Ba 6835 × B. 4578	High yield; resistant to gummosis.		×		1910	Department of Agriculture, Barbados.
S. C. 12/4	do	do	do	High quality; adapted to West Indies; resistant to gummosis.		×		1912	Do.
B. A. 11569	Female	do	B. 16536	Adapted to low rainfall		×		1911	Do.
B. 417	Male	do	B. 6835	High quality; resistant to gummosis.			×	1917	Do.
B. 726		do	Ba. 11569	Adapted to intermediate rainfall; high quality.		×		1922	Do.
B. 2935		do	Ba. 11569 × Ba. 6032	Adapted to low rainfall; resistant to gummosis.	×			1927	Do.
Burke		do	Unknown	General improvement			×	Before 1904	Do.
B. 147		do	do	do			×	do	Do.
B. 208		do	do	High juice quality			×	do	Do.
B. 376		do	do	do			×	do	Do.

B. 6308		do	T. 24	General improvement			×	1903	Do.
B. 6450		do	do	do			×	1903	Do.
Ba. 6032		do	B. 7169	do			×	1910	Do.
Puerto Rico:									
Fajardo Sugar Co.:									
F. C. 306		Fajardo	D. 433 × unknown	High yield; susceptible to gummosis and leaf spot.			×[2]	1915	R. A. Veve.
F. C. 436		do	D. 448 × unknown	do			×[2]	1918	Do.
F. C. 553		do	D. 433 × unknown	do			×[2]	1922	L. de Celia.
F. C. 588		do	do	do			×[2]	1922	Do.
F. C. 668		do	do	do			×[2]	1922	Do.
Mayaguez:							×	1926	R. L. Davis.
Mayaguez 28		Puerto Rican Agricultural Experiment Station.	P. O. J. 2725 × S. C. 12/4	Mosaic resistant; late maturity.					
Mayaguez 63		do	do	Resistant to mosaic; poor germination.			×	1926	Do.
North America, U. S. Department of Agriculture, Canal Point, Fla.:									
C. P. 807	Female	U. S. Department of Agriculture.	U. S. 1643 × unknown	Resistant to mosaic; great vigor; early maturity.		×		1924	E. W. Brandes. P. J. Klaphaak.
C. P. 27/139	do	do	P. O. J. 2725 × U. S. 1694	Resistant to mosaic and adapted to sawgrass muck.	×			1927	B. A. Bourne.
C. P. 28/11	do	do	Co. 281 × U. S. 1694	Early maturity; resistant to mosaic and red rot.	×			1928	Do.
C. P. 28/19		do	do	do	×			1928	G. B. Sartoris.
C. P. 29/320		do	Co. 281 × C. P. 27/34	do	×			1929	Do.
South America, Demerara:									
D. 74		British Guiana Department of Agriculture.	White Transparent	High yield; early maturity			×	1889	British Guiana Department of Agriculture.
D. 95		do					×	1889	J. V. Harrison.
D. 109		do					×		Do. (?).
D. 117		do					×		Do. (?).
D. 625		do				×		1892	Do. (?).
D. 1135		do				×			British Guiana Department of Agriculture.
D. 4930		do	D. 625		(1)				Do.
D. 66/30		do	Diamond 10 × S. C. 12/4						Do.
Diamond 10		Diamond Plantation	Unknown			×			Diamond Plantation, British Guiana.
Argentina, Tucuman:									
Tuc. 472		Estacion Experimental Agricola.	do	Resistant to mosiac and frost; very vigorous; early.	×				W. E. Cross, Estacion Experimental Agricola.

[1] Trial stage.
[2] Inferior to B. H. 10/12.

38143°—36——40

Table 5.—*World stations—past, present, and projected work, personnel, and expenditures*

Country and station	Date established	Seedlings studied	Uncontrolled pollinations	Controlled pollinations	Objective	Method: Variety crosses	Method: Species crosses	Method: Generic crosses	Commercial seedlings
		Number	*Number*	*Number*					
West Indies: Barbados	1887	200,000	150,000	[1] 50,000	Yield quality; resistance to gumming; arrowing sparse or absent.	Ba. 11569 × BH 10/12, Ba. 11569 × B 417, Ba. 11569 × S. C. 12/4, Ba. 11569 × B. 603, Ba. 11569 × Ba. 8069.	*S. officinarum* × *S. spontaneum*, *S. officinarum* × *S. sinense*, *S. officinarum* × *S. barberi*.		B. H. 10/12, S. C. 12/4, B. 726, B. 2935.
Puerto Rico: Fajardo	1914	32,023	9,353	[2] 22,670	High yield, rapid growth, late or nonflowering, resistance to drought, excessive moisture, mosaic.		P. O. J. 2725 × S. C. 12/4, P. O. J. 2725 × B. H. 10/12, B. H. 10/12 × F. C. 915.		F. C. 306, 915, 916, 1017.
Mayaguez	1917	121,450	2,500	118,950	High yield, vigor, sparse flowering, early maturity, shedding of leaves, resistance to mosaic, leaf-spot diseases.		P. O. J. 2725 × S. C. 12/4, P. O. J. 2725 × B. H. 10/12, M. 28 × P. O. J. 2878.	None	Mayaguez 28, Mayaguez 63.
Martinique		([3])				Ba. 6032 selfed; Martinique 23, 58, 302, 198, 158, 280, 161, 1132; Martinique 23 best.			
Africa: Mauritius and Reunion.	1883	([4])				Guingham × D. K. 74 [5].	M. 131 × D. K. 74, P. O. J. 213 × D. 109, P. O. J. 2725 × D. K. 74, P. O. J. 2725 × Co. 214, P. O. J. 2878 × Isautier (noble), P. O. J. 2878 × Uba Marot, P. O. J. 2878 × D. 96 (P. O. J. 2725 × Uba Marot), P. O. J. 2878 × D. 172 (P. O. J. 2725 × Uba Marot).		Isautier (1889).
Natal	1929	([6])							

Egypt	1930	([illegible])				Ba. 11569 × B. H. 10/12, Ba. 11569 × S. C. 12/4, B. A. 11569 × D. 1135, H. Q. 409 × S. C. 12/4 Diamond 10, D. 625 selfed.	U. S. 666 selfed, P. O. J. 2725 × U. S. 666, P. O. J. 2364 × S. C. 12/4, P. O. J. 2878 selfed, Co. 281 selfed, 26-C-148 × Molokai 1694, 28-1681 × 32-7665, Toledo × S. C. 12/4, M. D. 41 × B. H. 10/12, P. O. J. 2725 × S. C. 12/4.		
Reunion [8]	1889	(4)							
East Indies:									
Java	1886	(4)				×	Kassoer nobilization *S. officinarum* × *S. spontaneum*.	*S. officinarum* × *Erianthus sara*.	E. K. 2, E. K. 28, 247 B, D. I. 52, Tjepiring 24, S. W. 3, S. W. 111, S. W. 499, P. O. J. 36 and 36-M, P. O. J. 213, 234, 2725, 2878, 2883.
Argentina:									
Tucuman	1916	2, 600	600	2, 000	High yield; mosaic-resistance.	H. 109 × Yellow Tip: D. 666/18 selfed, S. C. 12/4 selfed.	H. 109 × P. O. J. 2878,[5] P. O. J. 2725 × Manoa 315, Striped Mexican × P. O. J. 2878, Co. 205 selfed, 4473-C selfed.	None	Tucuman 472.
Australia:									
New South Wales	1928	7, 400	1, 500	5, 900	Maturing 14 months; maturing 21 months; resistance to gumming, mosaic, leaf scald, Fiji disease; red rot, root rot "rust"; adapted to alluvial, peat, and poor soils; cold-resistance.		P. O. J. 2364 × 28 M., Q. 417, P. O. J. 2878 × 28 M., Q. 674, P. O. J. 2364 × B. 374, P. O. J. 2878 selfed, *S. officinarum* × *S. robustum*, *S. officinarum* × *S. barberi*, *S. sinense* × *S. barberi*.	do	None.
Queensland	1890	200, 000	[9] 25, 000	175, 000	Varieties resistant to disease and adaptability to soil and climate of various districts; same diseases as for Australia.	Orambo × H Q 409, S. J. 684a × S. J. 642c. N. G. 15 × S. J. 274a, N. G. 15 × S. J. 662b, S. J. 848c × N. G. 15.	P. O. J. 2878 × S. J. 672b, *S. officinarum* × *S. spontaneum*, *S. officinarum* × *S. robustum*, *S. officinarum* × *S. sinense*, *S. officinarum* × *S. barberi*.	do	Just commencing to be grown commercially.

See footnotes at end of table.

Table 5.—*World stations—past, present, and projected work, personnel, and expenditures*—Continued

Country and station	Date established	Seedlings studied	Uncontrolled pollinations	Controlled pollinations	Objective	Method: Variety crosses	Method: Species crosses	Method: Generic crosses	Commercial seedlings
Australia—Con.		*Number*	*Number*	*Number*					
Fiji and New South Wales.	1913, 1924	57,000	10,000	47,000	Varieties resistant to diseases as listed for Australia and to cane grub, weevil borer. Good ratooning; adapted to soil and climate of various districts		Crosses of hybrids of the sugarcane species: Badila × *S. robustum;* Korpi × *S. robustum;* Oranboo × *S. robustum:* F_1 back crossed to noble parent; F_2 back crossed to Badila and Korpi.	28 N. G. 7 (*Erianthus*) × Badila.	Broadwater 1, H. Q. 409, H. Q. 426 (Clark's seedling).
Philippine Islands:									
B. P. I. Manila [10]	1920	316,960		316,960			×		L. C. 25/191 (Aluman), Badila × 247B.
College of Agriculture, Laguna, P. I.	1919	126,123	[12] 6,956	119,167	High yield; resistance to major diseases of Philippines; adaptability to soil and climate of different districts.		×	None	C. A. C. 111, 117, 126, 127, 130; P. S. A. 7, 14.
Hawaii	1904	1,000,000	300,000	700,000	High sucrose content; resistance to diseases; rapid closing-in, good weed control. Freedom from tasseling. High yield per unit of time.	Yellow Caledonia × H-109.	*S. officinarum* × *S. spontaneum; S. officinarum* × *S robustum; S. officinarum* × *S. sinense; S. officinarum* × *S. barberi.*	Sugarcane × sorghum; sugarcane × *Erianthus arundinaceum.*	H-109, H-146, H-456, K-202, K-107, H-9806, U. D. 1, H-8965, 25 C 28, 28-2055, 28-1234, 28-1864, 31-1389, McBryde 7.
India:									
Coimbatore	1912	(13)	(4)	(4)	Early maturity; resistance to mosaic, red rot, and smut; adapted to various regions of India.	×	*S. officinarum* × *S. spontaneum* India, *S. officinarum* × *S. barberi.*	Sugarcane × sorghum.	Co. 205, 213, 214, 281, 285, 290, 313,[14] 331,[14] 357.[14]

United States: Canal Point, Fla.	1921	150,000	30,000	120,000	Early maturity; high yield; resistance to Mosaic, red rot, adapted to various sugarcane areas of United States.		*S. officinarum* × *S. spontaneum* Java, *S. officinarum* × *S. spontaneum* India, *S. officinarum* × *S. sinense*, *S. officinarum* × *S. robustum*, *S. officinarum* × *S. barberi*.	do	C. P. 807, 27-139, 28-11, 28-19, 29-320.
British Guiana: Demerara	1889	[4]			High yield	Nearly all crosses of varieties of noble canes.	Some seedlings from P. O. J. 2725.		D-74, D-95, D-109, D-117, D-433, D-1135, D-625, Diamond 10, D-49/30,[15] D-66/30.[15]

Country and station	Qualitative characters	Quantitative characters	Theoretical breeding	Cytology (chromosome number and behavior)	Elite breeding stock	Future investigations	Personnel: Early	Personnel: Present	Annual expenditures
West Indies: Barbados	Selfed lines; no results.	Progeny testing, cane number, weight, length, diameter, percent of sucrose	None	None	Not enough data.	Correlation, growth, types of seedlings to different environments and maturity and soundness of canes in stool during crop.	J. R. Bovell, J. B. Harrison, L. Lewton-Brain, F. A. Stockdale, J. P. d'Albuquerque, L. C. C. Leibenberg, S. H. Evelyn, —— Jenman.	A. E. S. McIntosh, G. C. Stevenson.	£5,500
Puerto Rico: Fajardo	None	None	do	do			R. C. McConnie, R. A. Veve, L. de Celia, R. Bermúdez.	J. E. Veve, R. Bird-Acosta.	$2,500
Mayaguez	do	do	Kassoer selfs; inbreeding.	do		Selfed lines; inheritance of disease; resistance to mosaic; sparse or late arrowing.		R. L. Davis	
Martinique							—— Littée	E. Bassières	
Africa: Mauritius and Reunion.					D. K. 74[5], M. 131, Uba Marot.		Dumesgnil, Bonâme, Perromat.	D. d'Emmerez de Charmoy.	Fr.100,000
Natal								H. H. Dodds	
Egypt							P. Neuville	H. H. Rosenfeld	
Reunion [5]								D. d'Emmerez de Charmoy.	

See footnotes at end of table.

TABLE 5.—*World stations—past, present, and projected work, personnel, and expenditures*—Continued

Country and station	Qualitative characters	Quantitative characters	Theoretical breeding	Cytology (chromosome number and behavior)	Elite breeding stock	Future investigations	Personnel		Annual expenditures
							Early	Present	
East Indies:									
Java	Selfed lines discontinued.	General characteristics of progeny from certain parents.		Varieties of all species and numerous hybrids.	P. O. J. 100, E. K. 28, Kassoer, P. O. J. 2364.		J. D. Kobus, Krüeger, W. Moquette, J. H. Wakker, Soltwedel, J. W. Versteegh, R. J. Bouricius, J. G. de Kock, J. P. Bannier, E. Karthaus, G. Wilbrink, J. Jeswiet.	O. Posthumus	
Argentina:									
Tucuman								W. E. Cross	
Australia:									
New South Wales						Stalk size; disease resistance: cytology of species and hybrids.		H. Wenholz, W. H. Darragh.	£1,500
Queensland						"Pure" lines; disease resistance and vigor.	W. Mitchell	A. F. Bell, E. J. Barke.	[11] £1,200
Fiji and New South Wales.			Selfed lines, showed no promise, discontinued.			Correlation of seedling and mature cane characters.	James Clark, W. A. Speight.	H. F. Clarke, J. Trivett, K. R. Gard, D. S. North.	
Philippine Islands:									
B. P. I. Manila [10]							A. Labrador	None	
College of Agriculture, Laguna, P. I.	Anther color and pollen ferility.	Diameter, length, and number of stalks; cane tonnage; sugar yield.	Six types isolated from Badila selfed seedlings.					N. B. Mendiola, T. Mercado, J. M. Capenpin.	$2,500

Hawaii	Eyespot resistance.	Studies on inheritance of sucrose content.		×		Mass fertilization; inheritance of sucrose content and resistance to more important diseases.	C. F. Echart, W. Twigg-Smith, Y. Kutsunai, J. A. Verret, W. W. G. Moir, H. P. Agee, W. P. Naquin, W. C. Jennings, W. P. Alexander, C. F. Poole, Raymond Conant, J. A. H. Wilder, J. S. B. Pratt, Jr., E. G. Clark, G. C. Watt, J. N. P. Webster.	A. J. Mangelsdofr, C. G. Lennox, A. D. Waterhouse, Douglas Thomas.	
India: Coimbatore					Co. 205, 206, 213, 221, 281, 290, 312, 313, P. O. J. 213, P. O. J. 2725, P. O. J. 2878, 247 B.		C. A. Barber	T. S. Venkatraman, N. L. Dutt.	
United States: Canal Point, Fla	Inheritance of resistance to mosaic and red rot.	Early maturity and yield.	*S. officinarum* × *S. spontaneum* inheritance of mosaic.		U. S. 1643, C. P. 1165, 1161, P. O. J. 2725, 2878, Co. 281, C. P. 29-290, 27-108.	Cytology; inheritance of disease resistance; progeny testing.	E. W. Brandes, P. J. Klaphaak, B. A. Bourne.	G. B. Sartoris, J. W. Strickland, R. T. Gibbens, Jr.	
British Guiana: Demerara					D-625, D-145, Diamond 10, D-238/17, S. C. 12/4, P. O. J. 2725.		J. B. Harrison. — Jenman.	C. H. B. Williams, R. R. Follett-Smith, C. Cameron.	

1 Date begun, 1922.
2 Date begun, 1926.
3 Produced a few seedlings.
4 Numerous.
5 D. K. 74.=D. 74.
6 Seed imported.
7 Seed imported from Hawaii, United States, Barbados, Mauritius, Puerto Rico, Demerara, and Queensland.
8 Discontinued soon after started. Work renewed recently. See Mauritius.
9 Discontinued, 1928.
10 Work discontinued 1932.
11 Salaries and wages not included.
12 Discontinued.
13 Many thousands.
14 Experimental stage.
15 New seedlings showing great promise.

Improvement of the Sugar Beet

By G. H. Coons, Principal Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry

SUGARCANE and sugar beet are the important sources of sugar. This foodstuff, which today is one of the purest and cheapest in our dietary, two centuries ago was a luxury available only to the rich. The story of the rise of sugar production to meet an ever-increasing demand is a romance of agriculture and chemistry. The accomplishments of the plant breeder and the chemical engineer in making this contribution to the world's food supply rank in significance with such important contributions to human welfare as the introduction of the potato or the invention of the cotton gin. Today sugar is a part of the diet of everyone, and the per-capita consumption is associated with the standard of living of a nation.

It is a common statement in this series of articles on breeding and genetics that the wild progenitors of our crop plants are not known; there are diverse opinions, in many cases, even about the places of their origin. Primitive peoples wrested these plants from nature, improved, and conserved them. They come to us as the heritage of the past, the steps in their development being matters of surmise or conjecture. We can reconstruct the course of their development only on the basis of our own experience or from the theories of plant and animal evolution and dispersal.

In the article on sugarcane a glimpse is afforded of the probable course of development of this plant. The observations by Brandes (*6*) on the nurture of sugarcane among the primitive tribes of New Guinea supply a pattern of the course which the aborigines at a similar stage of development may have followed with their food plants. The tribal beliefs and practices reported by Brandes throw light on primitive methods of selection and husbandry, and they indicate what mankind at the dawn of history probably did with various plant forms on which he was dependent.

In sharp contrast to this reconstruction of the past and inference concerning it, we deal in the case of the sugar beet with a development reaching back not more than 150 years. The winning of this sugar plant from the common stock of beets used chiefly as feed for animals was done by known historical figures who left some written record of

their accomplishments. It is a story of man's success, through a century and a half of endeavor, in adapting a plant to highly specialized use.

The consideration of other crop plants turns our glance backwards to the unknown and legendary "plant improvers" as man emerged from savagery. We must postulate enormous stretches of time for improved varieties to evolve. The story of the sugar beet, on the other hand, is a record of scientific achievement. A brief span of time is involved. It is an epic of modern science.

The History of the Sugar Beet—One of the Few Plants Developed in Modern Times

THE sugar beet as we know it today and the great industry which has been built up about this plant date back to the work of two men—Marggraf, who made an epochal scientific discovery, and Achard, his student, who applied this discovery with zeal and genius.

In 1747 Andreas Sigmund Marggraf, a German chemist, found in two cultivated species of the beet family a sugar identical with the sugar then known as "cane sugar." In his scientific report, the chemical methods of extraction were described, the proportions found in the plants tested were given, and he stated that the crystals of sugar could be recognized under the microscope in the dried slices of beet (*18*).[1] There is little doubt that Marggraf was aware of the significance of his discovery, but apparently he made no attempts to apply it.

The application of the finding and the gigantic task of developing technological methods and creating an agriculture on which to base an industry were the contributions of Achard (*1*). In 1786 Achard began his classic researches on the extraction of sugar from fodder beets. The kinds of beets existing at the time were probably a complex mixture of which the predominating types were those akin to what we know today as mangel-wurzels. In the closing years of the eighteenth century, Achard's experiments were successful. A factory project, underwritten by funds granted by Frederick Wilhelm III of Prussia, was launched at Cunern in Silesia, Germany. The report referred to was written at the close of the first year's campaign of this factory.

Achard coined the term "beet-sugar," and in the press "sugar beet" began to be used to designate the beets he favored for fabrication of sugar. As may be determined from Achard's writings and the seed lists of the period, these beets were mixed stocks of red or white mangel-wurzels, undoubtedly hybrids—some having red flesh, some white flesh. These were in common use by the farmers around Magdeburg, Germany, where Achard carried on his early work and obtained his seed supplies. Although they were chiefly grown for the feeding of livestock, it appears that the peasants of this section also used beets to make a table sirup. This use may, perhaps, have

[1] Italic figures in parentheses refer to Literature Cited, p. 650.

played a significant role in conserving the sweeter types which otherwise might have been dropped from culture.

NEED FOR BREEDING WORK RECOGNIZED IN 1809

When the small factory was started, although he was beset with technological difficulties in manufacturing sugar from the low-quality beets available, Achard gave much attention to the agronomic and economic problems involved in the production of beet roots suitable for the factory. In his early writings he listed the existing types of beets and evaluated them from the standpoint of purity and sugar concentration. From the beginning of the small factory at Cunern, he was groping among the conglomeration of types in the mangel-wurzel complex to find those most suitable for fabrication, saving the better sorts and raising seed from them. By 1809, Achard clearly recognized that the future of the industry depended on securing suitable varieties and that they could come only as a result of breeding work. The little factory made sugar from beets whose average sucrose percentage was far less than half that of present-day sugar beets.

Achard did not achieve commercial success in his venture nor complete his plans for beet improvement. His factory failed, and he died a disappointed man. But he had contributed an idea to the world and opened a new field for human endeavor.

In these early years of development, the name of Freiherr von Koppy is linked with that of Achard. Shortly after the first success in obtaining sugar from beets in Silesia, Koppy erected a factory at Krayn, Germany, and interested himself in the selection of improved types. The record seems clear that Achard generously aided Koppy by supplying seed and technical assistance for what some might have considered a rival enterprise. Achard's factory operations ended in 1810, but Koppy continued his attempts to maintain a factory until about 1820, and even after it closed he kept on with his selection work with improved strains of beets. From this work came the White Silesian beet, which the historian Lippmann (*17*) denominates "the mother stock of all the sugar beets in the world."

On the foundation laid by these pioneer efforts, the sugar industry arose. The succeeding steps can only be mentioned briefly to bring out the events of the last century that have a direct bearing on the theme of this article. The histories of sugar and of the sugar beet by Lippmann or Vilmorin (*26*) should be consulted for a complete account.

The attempts to establish factories were abandoned in Germany for the period from 1815 to 1830. Activities in sugar production centered in France under the impetus given by Napoleon's Decree of March 25, 1811. In order to strike a blow at the trade in sugar from British colonies, the French Emperor subsidized factories and ordered the growing of large acreages of sugar beets. It may be said that the French industry grew out of the experiences of Achard, and the White Silesian beet was introduced for factory use and for improvement by seedsmen. Breeding work with sugar beets was begun early in this period of development in France.

In 1820 Philippe André de Vilmorin reported results of his selections based on morphological characters. His work was carried forward by his brilliant son, Louis. The science of plant breeding credits Louis

de Vilmorin with formulating the principle according to which the breeding value of the mother plant was determined by the quality and characteristics of its progeny (*13*). Vilmorin applied this principle in sugar-beet breeding, evaluating the progenies according to dry substance as determined from density values (silver-ingot method). In 1853 these values were checked by sucrose determinations obtained by use of the polariscope. In the hands of Vilmorin the improvement of the sugar beet was definite and rapid. In his Notes on Some Varieties of White Sugar Beets, published in 1861, Vilmorin states that in the strain then in process of development by his method, certain lots contained from 16 to 17 percent of sucrose, in comparison

THE *United States has imported the greater part of its sugar-beet seed. In general, about 15,000,000 pounds were brought in annually in the period from 1920 to 1933. As a result of recent experiments, a seed industry is being rapidly built up in New Mexico, Utah, Nevada, California, and Arizona which now promises to supply nearly one-third of the seed requirements of the United States for 1937. This domestic seed production definitely interlocks with breeding work. We may expect steady expansion of the industry, and with it greater developments in breeding to provide improved and tested supplies of foundation stocks. The interest that is being aroused in the subject of sugar-beet improvement is extremely encouraging. As the problems are understood and the needs are properly visualized, there is little doubt that the American industry will take up the challenge.*

with the Imperial beet—produced by German breeders—which contained only 9.8 to 11 percent. Both of these forms showed great superiority over the ordinary white sugar beet in common use, which tested only 7.5 percent.

IMPROVED METHOD OF TESTING MAKES SELECTION MORE CERTAIN

Between 1860 and 1875 polariscopic analysis of the juice as a guide to selection came into use in various beet-breeding establishments. The radical improvement in sugar-beet quality may be said to date from the introduction of this technique and its application to the breeding principle established by Vilmorin.

In root shape, color characters, and foliage, the sugar beets worked by Achard and Koppy probably resembled the sugar beet as we know it today. We must infer that the White Silesian variety was a population containing high- and low-testing individuals, together with their hybrids, and that as a whole these gave a low percentage of sucrose. Schribaux (*22*) is the authority for the statement that in the period from 1838 to 1868 when morphological selection prevailed, the average richness in sucrose progressed from 8.8 to 10.1 percent. From 1868 to 1888 it mounted to 13.7 percent and from 1888 to 1912 to 18.5 percent. Other tabulations, based chiefly on computations from statistics of sucrose production, are prone to indicate that each decade following the general use of the polariscope by breeding establishments in Europe has shown a steady and mounting gain in sucrose and yield. It seems probable that in such summarizations the improvement in factory methods which took place at the same time has not been fully taken into account.

In 1880 Ware (*27*) described the varieties or commercial brands then existing. These descriptions clearly show the improvement that had taken place to this date. His statements as to sucrose percentage for the various brands and their yields per acre indicate that sugar-beet types rather closely approaching those of the present time in quality and yield had been separated from the mother stock. The data taken from the experimental plantings of sugar beets in the United States under the direction of Harvey W. Wiley, of the Department of Agriculture, in the period from 1885 to 1908 (*28*), also bring into question the common opinion that there was a steady and continuous improvement. In Wiley's tests standard European brands were used in many localities, as well as home-grown seed derived from local selections, and the tests gave data fairly consistent with results obtained in American beet districts in the last decade. From 1900 (*21*) various other tests with European brands were made along the line of Wiley's early work. These too approximate the results with present-day tests. Records of factories started in 1900 or slightly later reveal that the sugar beets used were not strikingly different from those of the present day.

It seems important to call attention to this evidence as to the quality of sugar beets at a period during which it is common to assume that the quality was much lower. For one thing, the accepted belief that the sugar beet has shown steady and increasing gains in quality and yield each decade since 1880 is difficult to harmonize with the genetic considerations involved. If this were true, it would seem perhaps to make marked departure from present methods unwarranted. It is suggested that each period of development made its contribution to the technique of selection, and as the new factor entered, its effects were rather promptly secured. In the interim periods, the work of the breeder may have been to hold the advance gained and to maintain the stocks free from outside contamination.

This rapid review brings out certain points significant to the sugar-beet-improvement program. In the early work the less desirable portions of the mixed population were separated out and discarded by slow degrees. There was an advance with each development in method whereby reliable selections could be made. Most significant of these was the development and application of the progeny test. Its full effects could come only with the discovery of an efficient and

accurate means of determining richness in sucrose. Hence marked progress followed the introduction of the polariscope to test individual beets and composite samples. From this time on, it was possible accurately to compare individuals through the behavior of their progenies, and to retain a population in which hybrids of desirable types predominated.

This brief account has also stressed the point that sugar-beet varieties as we know them today trace back to the White Silesian beet of Achard and Koppy. Since they come from this common source, the potentialities for development in the present varieties lie within the genetic limits of the basic material. With each successive step in selection, we may conceive that the previous gene complement may have been reduced. These considerations are significant when the problems of further development are faced. We may surmise, for example, that desirable potentialities have been dropped by the way and must be found again. This opens a broad field to be explored.

We do not know what additional desirable characters there are within the varieties as they exist today until work proceeds in new directions to separate forms adapted to special conditions of soil or climate, or resistant to disease. The achievements of the past forecast future possibilities for new and useful discoveries.

THE METHODS USED IN EUROPEAN SUGAR-BEET BREEDING

From the preceding outline, it is clear that from the very beginning of the industry, plant breeders in Europe concerned themselves with beet improvement. As the industry grew in size, the efforts increased, and seed firms which at first used only simple methods developed into highly specialized beet-breeding establishments seeking to secure improved strains and to furnish a trustworthy product.

The methods of sugar-beet breeding followed by European firms producing seed for American use are similar in their essential features. The product is marketed under brand designations, usually consisting of the name of the firm and a letter, name, or symbol to indicate the type, that is, whether a high-sucrose strain, a high-yield producer, or a "compromise" or intermediate type. It is the common experience that the types analyzing highest in sucrose produce lower tonnages than the high-yield types, while the latter in turn commonly show a lower sucrose percentage. The so-called compromise types are expected to take an intermediate position.

The firms with which contact has been established apparently follow a system that may be designated as "mother-line breeding." As will be clear from table 6 on page 655 in the appendix and figures 1 and 2, which show commonly used methods, it is meant by this that the pedigree starts with a mother beet, often selected as a result of polariscope tests of many beets. Seed is obtained from this mother beet, more or less effort being made to eliminate outpollination of the mother plant. A progeny is grown from a portion of this seed, and the performance of the progeny is compared with the performance of progenies similarly produced from other mothers. Selection is based on the performance of the progeny. If a progeny is satisfactory, the reserve seed arising from the mother plant is used to give stecklings from which to secure a considerable quantity of

seed and roots to continue the "line." [2] Usually tests are made of the progenies arising from this increase before the best are pooled together to give an "elite stock" from which to produce commercial seed.

Since the performance of the progenies is reasonably well known from the tests, it is possible to make the poolings to produce brands of the general types desired

European Breeding Retains Many Diverse Characters

The method of seed production followed in Europe is from the stecklings, produced by growers to whom the elite seed is furnished for this purpose. An attempt is made to have the seed fields reasonably isolated from fields of sugar beets of different type or brand, and from mangel-wurzels grown for seed. The sugar-beet seed is cleaned, then blended to produce a product of uniform grade conforming to the trade standards. The use of the designation "original" is in some countries restricted by law to seed produced by direct increase from an elite stock furnished the grower by the company selling the seed under its brand designation.

The practices in sugar-beet breeding followed by the various companies deviate in various ways from the schemes outlined, but do not depart from the general principle involved. In its essential features the method commonly used [3] corresponds to the ear-to-row method used with corn to secure selected ears from which to plant a seed plot. The number of years devoted to test of beet progenies may vary, and the emphasis given to certain features may differ. It is to be noted that only 1 year of inbreeding is employed. The most salient variation probably occurs in the method of isolating the mother beets.

The statement is commonly made that sugar beets are the product of mass selection. From the methods followed, it is evident that beet seed is not produced by mass selection of the roots that are to furnish the commercial seed. The mass selection is based on progeny performance, and the seed of selected progenies are pooled. This in turn produces the commercial seed. The great divergence of types which show up in every field indicates clearly that the methods followed do not lead to uniformity in foliage or root characters, except as these may be correlated with quantitative characters such as sucrose percentage, yield tendencies, and the like, on which selection is based.

Information is not complete for all firms, but judging from published statements and information furnished, the methods used follow three main lines. Certain firms produce seed of a given type by securing a large number of progenies of satisfactory performance and massing them. Other firms seek a smaller number, one firm using about a dozen lines, each tracing back to a selected mother. Still others use a smaller number than this. It must be borne in mind that these lines are seldom pure lines as the term is used by the geneticist. They are collections of hybrids which may be said to have a satisfactory uniformity in certain physiological characteristics, for example, sucrose percentage. Thus, when they are massed, many more diverse elements are included than might be expected from the limited number of initial progenies.

[2] The stecklings are small beet roots produced by close spacing of the plants. These are stored (siloed) over the winter and replanted to produce seed the following year.

[3] A method is also illustrated in which an attempt is made to determine the best combinations of "lines" to use in production of commercial seed.

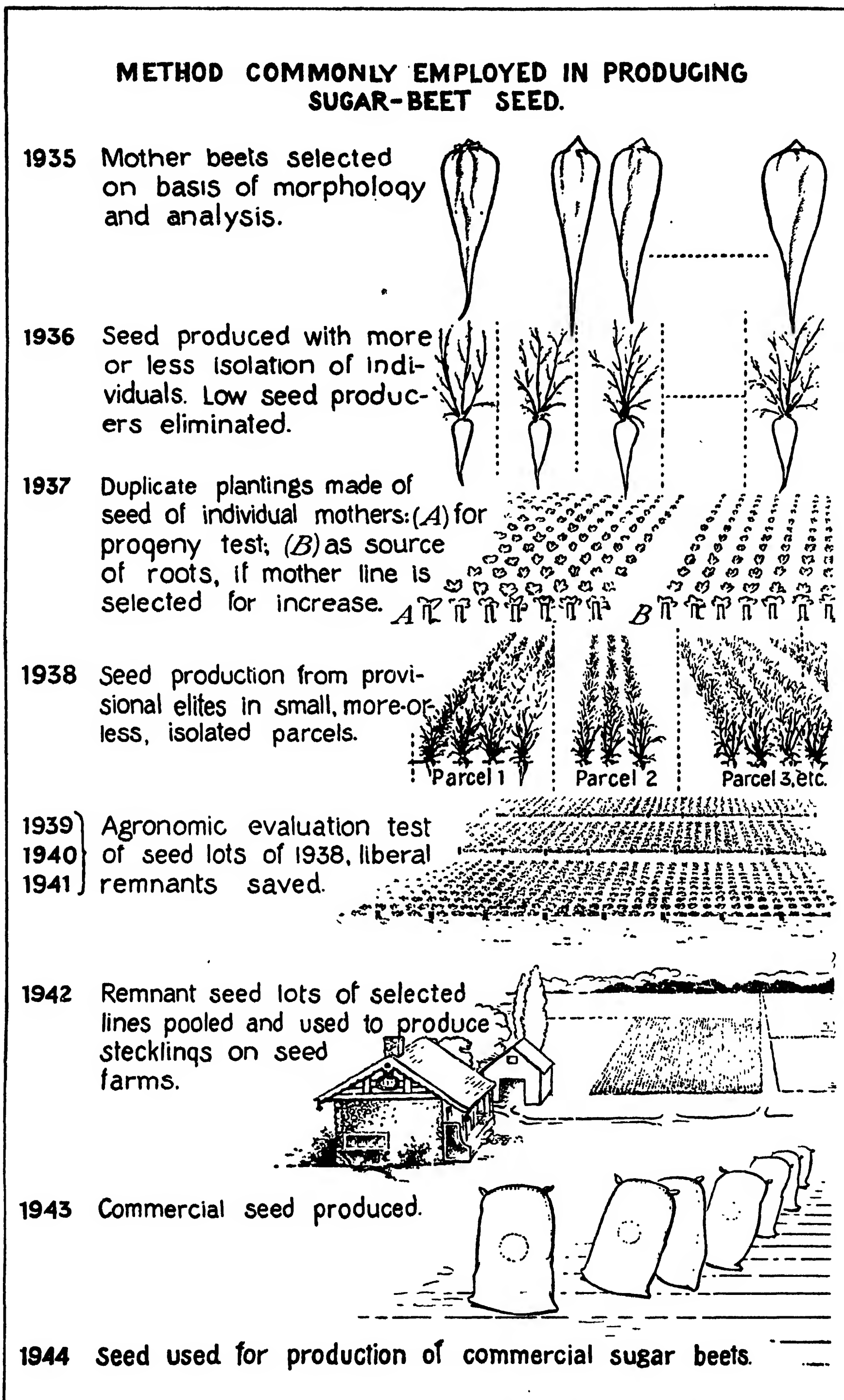

FIGURE 1.—Diagrammatic representation of European method of producing sugar-beet seed. At some establishments the evaluation tests are made with seed from original mother roots, and seed production shown for 1938 follows these tests.

The methods employed for seed production in the Union of Soviet Socialist Republics (*20*) are not at present distinctly different from those employed in other European countries. According to the Russian prospectus, an ingenious use is made of fall plantings, presumably in small isolated parcels, which should permit testing of progenies 1 year in advance of the main production contemplated. It was stated to the writer that the inbred lines produced by the intensive breeding investigations at Belaya Cerkov and Kiev, Union of Soviet Socialist Republics (*2*), were not as yet used to produce commercial seed.

With the majority of European firms, selections of mother beets are made each year to start the series over again and produce seed for the next commercial crop. The new mothers are usually taken from breeding plots, and their lineage on the mother's side can be traced. Hence in the records of the various firms, pedigrees of the mothers can be followed, going back perhaps many generations to a single ancestral beet.

Possibilities for Securing Special Characters Are Limited

In animal breeding, line breeding would be expected to result in remarkable intensification of certain characters arising from the sire. But it must be understood that the cases are not parallel. Whereas with animals the matings are controllable, in the case of the sugar-beet mothers, with the methods usually employed, the situation is one of polyandry. It seems probable that even though the mother line is traceable at each generation, the chance is strong that pollen of a diverse line entered to modify to a large extent the intensification expected. A factor which undoubtedly operates to favor selecting cross-pollinated individuals as against those largely self-pollinated is the choice of mothers that are heavy seed producers. As is well known from breeding experience, the yields from selfed beets are often extremely low and, though not always, the higher yields come from out-pollination.

It must be conceded that if selections were always made among beets that had the same grandmother, great-grandmother, great-great-grandmother, and so on, it would be expected that the cross pollinations would become more and more narrowed to those coming from the ancestral mother stock. But the generally insufficient isolation and the selection of mother beets for high seed yield mentioned above operate to nullify the effects of the attempts at lining and may even result in diverse lines being established within a pedigree that, on paper, apparently precludes such a contingency.

Thus the common observation that a sugar-beet field, no matter what the brand, presents a conglomeration of types serves to show that there is little approach to the intensification of certain characters that might be expected from the pedigrees of the beets.

Critical analysis of the method, therefore, explains the apparent contradictions between the pedigree showing and the actual results. It seems evident that the method serves to sort the progenies of the mother roots into certain grades according to physiological performance—as sucrose percentage—and that this sorting may be accomplished rapidly. Then, as the limits set by inheritance are approached, further improvement is probably slow. It also seems clear that the method cannot be expected to give progenies with special characters,

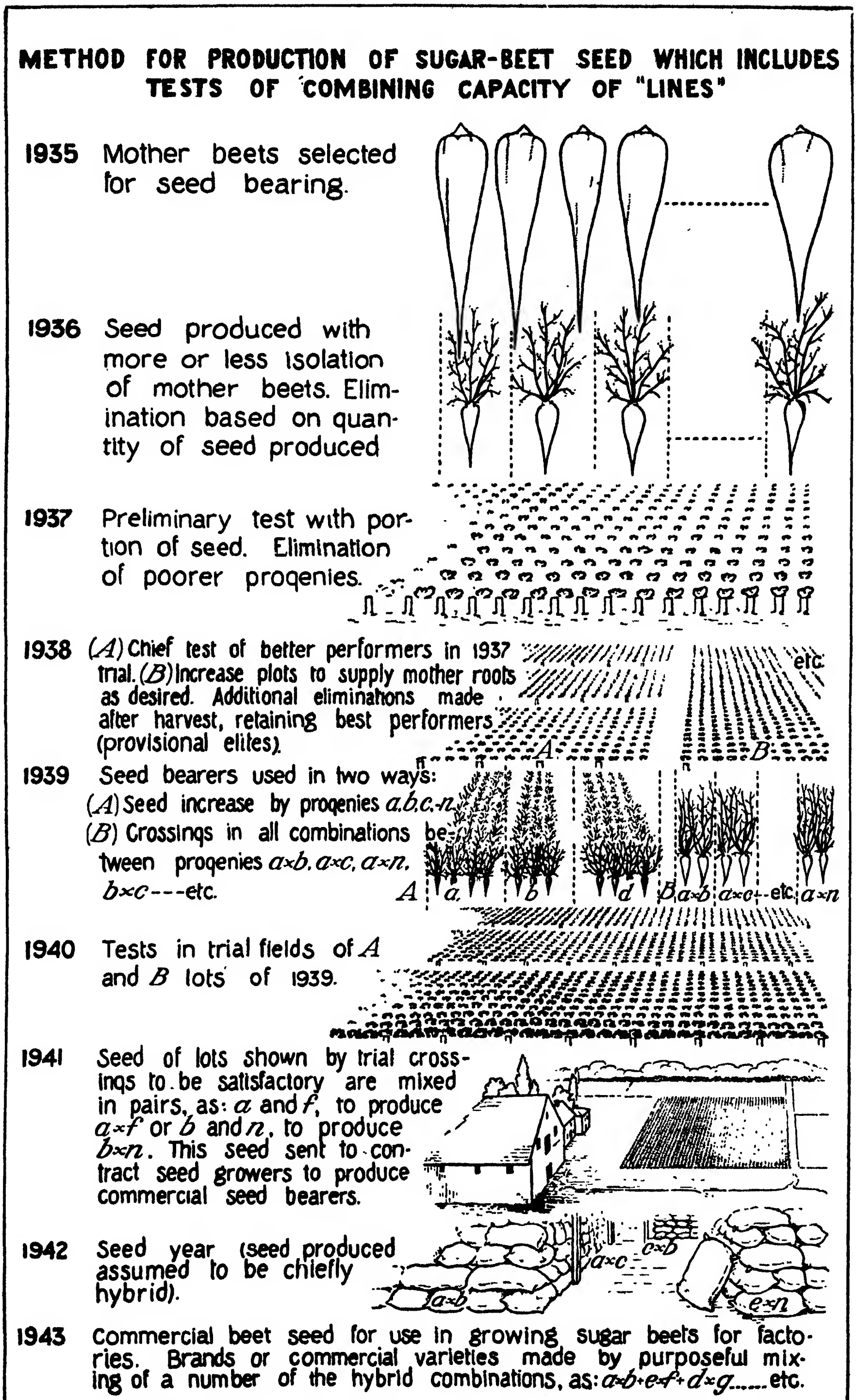

FIGURE 2.—The method of producing sugar-beet seed coming into use in certain European seed establishments. It offers the advantage of tests of combining capacity of lines prior to final large-scale making of combinations.

such as resistance to disease, unless provision can be made for rigid selection for the desired character. It would appear also that massing of many progenies would tend to nullify any advance made with a limited number. The method is apparently adequate to hold the progress made by narrowing the population to the types that possess

THE sugar beet as we have it today may have lost important factors in the course of its development, or there may be exceedingly valuable new genes which might be introduced. Two avenues are open for experimental exploration in the search for new genes—the cultivated plants with which the beet readily hybridizes, and the wild species of the genus. Also of exceeding interest in practical breeding work is the reaction which follows hybridization of inbred lines. The general average of 41 hybrids was an increase in yield of 39½ percent over the commercial variety used as a check, the highest yielder showed an increase of 65.7 percent.

certain characters in common and to get rid of any serious admixture of chard, mangel-wurzel, or red garden beet. But the performance of the variety or brand obtained in this manner may be expected to be the average of its many components and to show little change as one series follows in the steps of its predecessor.

Breeding Sugar Beets to Meet the Special Needs of Growers in the United States

THE system followed in Europe, then, is a mass-selection scheme based on progeny performance—the Vilmorin method—coupled with attempts to maintain certain mother-beet lineages. That noteworthy progress has been attained by this method is evident. The results may be judged from the performance of European beet seed in the United States, which shows that seed purchased from a reliable firm is commonly true to its brand characterization and almost always free from serious admixture with red garden beets, mangel-wurzels, and Swiss chard. Farmers may use this seed with a high

degree of assurance that crop yields will be satisfactory under favorable conditions for growth and development.

But American conditions for growth and development are not always favorable, nor do they parallel the soil and climatic conditions under which the seed was developed. In developing his various brands of sugar beets—the so-called sugar type, the intermediate type, or the tonnage type—the European seed producer sorts out the hereditary combinations as well as possible to conform to these categories. Because it is a complex mixture of potentialities, the same brand of seed may suffice for the eastern United States, the Rocky Mountain region, and the Pacific coast. Under such diverse conditions, one portion or another of the population thrives—but conversely certain portions may be totally unsuited to the conditions. It is clear that a variety adapted to a given area should perform better than one whose performance is an average of good, mediocre, and poor producers. This point has long been recognized, and home production of seed has been urged by the United States Department of Agriculture and various experiment stations as a logical step for improvement of sugar-beet crops.

In table 1 (p. 652) are listed the important projects in sugar-beet breeding undertaken in the United States. The list is of interest for its record of efforts that did not persist as well as those that show present trends. The small number of commercial firms engaged in these efforts is significant. In many areas, European sources are depended on entirely for seed supplies. So long as the policy of purchasing seed abroad is continued, the general level of performance in these districts probably will not be greatly altered.

With other crops, even those that are cross-pollinated and comparable to the sugar beet, no such system of importing seed supplies from a distance prevails. In the case of the corn crop, for example, increasing attention is given to securing varieties adapted to the soil and climatic conditions in a given area. The superiority of the product from home-grown seed is generally accepted. With full recognition of the good average performance of the high-grade brands of sugar-beet seed now imported for American use, it must be frankly pointed out that the European methods have their inherent limitations which make it essential that breeding work with new aims be carried on if adequate attention is to be given to some very definite requirements of the American beet grower.

The importance of this to American agriculture can probably best be brought out by considering the part played by epidemic plant diseases in recent years. These disease hazards to our crops are as much a part of growing conditions as the general factors included in soil and climatic effects. In the western United States, curly top is the limiting factor in sugar-beet production; in the areas east of the Rocky Mountains, Cercospora leaf spot or "blight" is a problem of major importance.

Since 1900 western growers and operators have been asking the European producers of seed for varieties resistant to curly top. The losses in the period from 1900 to date from curly top have been enormous; crop failures have been frequent because of this disease. For an equally long period there has been a demand for strains resistant to Cercospora. Since curly top does not occur in Europe and since Cercospora leaf spot very rarely reaches serious proportions in the seed-breeding areas of northern Europe, little or no progress has been

made in meeting the American demand. Tests of the leading brands of European seed have shown that without exception they lack, as brands, resistance to these diseases. But it is noteworthy that within these brands individuals have been found more resistant than their fellows. The sorting out of these resistant individuals can be done only under conditions in which the disease occurs as a severe outbreak (*9*).

The heavy losses and the occasional crop failures in certain districts from sugar-beet diseases, which may be conservatively stated as amounting to many millions of dollars a year, show clearly that the development of resistant sorts is a most pressing need of the American industry. The magnitude of the losses gives some indication of the return to be expected from successful efforts in this direction. Resistant varieties will not only mean increased income for the farmers; the control of these epidemic diseases will also have a stabilizing effect on production (*3*). The importance of investigations looking to the development of varieties of sugar beets safe from disease has in the last 13 years been fully recognized by the Division of Sugar Plant Investigations (*5*).

Resistance to Curly Top

The history of the experimental work looking to the development of curly-top-resistant varieties dates from 1902. Carsner (*8*) has reviewed these early experiments and appraised their contribution. Although they did not result in the development of strains suitable for use, these attempts demonstrated that from the complex of hereditary combinations existing in commercial brands of sugar beets, highly resistant components could be separated. It may be remarked that this finding, which today is accepted without question, was strikingly at variance with a rather pessimistic belief on the part of many European breeders as to such a possibility.

The first curly-top-resistant variety furnished growers for commercial use was produced by Eubanks Carsner and D. A. Pack in 1929 and came into extensive use in 1934. It was released under the designation U. S. 1 (*8*) (fig. 3). After intensive test in the western United States in 1930, 1931, and 1932 by members of the Division of Sugar Plant Investigations, steps were taken to make this variety available as the means of combatting the destructive course of curly top. The details of the development of this variety, the results of the tests, and an outline of the methods used in securing rapid multiplication of seed to commercial proportions are given in the publication cited.

The variety was produced by growing for seed production the highly resistant individual roots taken from progenies of mother roots that had been selected from fields and experimental plots in which curly top exposure had been severe. Table 2 (p. 652) gives the data concerning seed production for this variety and an estimate of the acreage on which it has been used.[4] Its prompt acceptance and the expansion of its use to the limits of the seed supply is evidence both of the need and of the performance of the variety under curly top conditions.

Detailed account of tests with this variety in 1932, 1933, and 1934 has been published (*24*). These tests have shown a general superior-

[4] Acknowledgment is made to H. A. Elcock, sugar-beet seed committee, F. S. Ingalls, Utah-Idaho Sugar Co., and the Farrar-Loomis Seed Co. for data as to commercial sugar-beet seed production in the United States.

ity over commercial brands amounting to at least 2 tons per acre under moderate curly top exposure, and reaching 5 tons or more per acre, as indicated by the preliminary tests, when curly top was severe. The sucrose percentage of the variety has always been high, in many cases exceeding that of the commercial brand with which it was compared.

Because of the emergency, the variety was released before it was perfected in curly top resistance or with respect to certain other characters. For example, it has a tendency to bolt, which precludes its utilization for winter plantings in California. Effort has been concentrated on improving and stabilizing the variety, and as improvement has been accomplished new foundation stocks have been furnished for increase, looking to their use by growers. In tables 2 and

FIGURE 3.—The curly-top-resistant variety U. S. 1 (left center) compared with a commercial brand (right) at King City, Calif., in 1934. The U. S. 1 variety yielded at the rate of 13.6 tons per acre, the commercial variety 2.5 tons per acre. (Spreckels Sugar Co. test, photographed by E. Carsner, May 23, 1934.)

3 (pp. 652, 653) details are given of two new releases, designated as U. S. 33 and U. S. 34, which were obtained as mass selections from U. S. 1. These selections were made by F. V. Owen and F. A. Abegg in 1931 from fields in Idaho in which curly top was extremely severe.

The data on the performance of U. S. 33 and U. S. 34 have not been fully evaluated, but these two varieties represent a decided improvement in curly top resistance over U. S. 1. In some experiments, the superiority of U. S. 34 over U. S. 1 seemed almost as striking as that of U. S. 1 over commercial brands with which it was compared. Under conditions of severe curly top exposure, U. S. 34 has produced upwards of 10 tons per acre, U. S. 1 about 7 tons, and commercial brands from 2 to 3 tons. The sucrose percentage has been maintained at a high level. As will be noted from the tables, seed of U. S. 34 has been increased in greater amount, and this variety will replace U. S. 1 in the production of sugar beets for fac-

tory use in the curly top areas beginning with 1936. Present indications are that this curly-top-resistant variety will be used almost exclusively in some districts. U. S. 33, which produces a slightly higher sucrose percentage and has less bolting tendency, will probably come into large-scale use in 1937.

Breeding work to secure curly-top-resistant strains of sugar beets is being continued. It is expected that from time to time new improved material can be furnished as foundation stocks to replace existing material. As illustrative of the program, table 4 (p. 653) has been compiled to furnish a partial list of promising varieties and strains being submitted to intensive agronomic tests in the curly top area to determine their suitability for future commercial use. It will be noted that, in addition to curly top resistance, the strains are being tested as to bolting tendency in order to secure varieties adapted to the present program of sugar-beet planting followed in California. As will be seen from the sources of material listed, some trace directly to U. S. 1 and arise from small groups of selected mother beets chosen for outstanding curly top resistance; others trace back to the original strains utilized by Eubanks Carsner and D. A. Pack in producing U. S. 1; one variety is listed from selections made for curly top resistance at State College, N. Mex. The progenies from single mother beets of exceptional resistance, which are the starting point in the development of pure lines, cannot be evaluated as yet because they have not progressed far enough toward a homozygous condition.

Resistance to Cercospora Leaf Spot

The problem of securing strains of sugar beets resistant to leaf spot has received attention since 1925. At the outset of this work, no varieties outstanding in resistance from which to make selections and to serve as a starting point for improvement existed, with the exception of the Leaf Spot Resistant variety developed by Skuderna (*23*) from an early selection made by W. W. Spencer.

The methods followed in breeding for Cercospora leaf spot resistance have been reported from time to time (*3*) and statements given of results. Selections made under severe leaf spot epidemic have been tested, and the results show that some progress can be made in this way. The nature of the disease and the absence of immune or strikingly resistant individuals in present commercial brands have made it practically impossible to select on the basis of the degree to which leaves are affected. However, by use of the criteria of weight development and high sucrose percentage under leaf spot conditions, strains have been obtained that are strongly improved in their reaction to leaf spot. The advance made, however, has not been so marked as to warrant belief that simple field selection will meet the difficult problem presented.

The attack, therefore, has centered chiefly on the use of selection and inbreeding to secure lines of beets stabilized in leaf spot resistance to serve as a basis for production of hybrids or synthetic varieties. It has been found that as inbreeding has continued, the lines under study have lost vigor but maintained their capacity for sucrose storage. The lines secured to date, while high in leaf spot resistance, are not heavy enough producers to be suitable for use in commercial sugar-beet production.

The problem then has resolved itself into the accumulation of leaf-spot-resistant lines and the use of these lines in various combinations to find those that prove to be superior upon hybridization, either as a single or a double cross, or as a synthetic variety—a combination of several desirable inbreds (fig. 4). Because of the sporadic nature of leaf spot outbreaks, the performance of the varieties must be satisfactory not only under Cercospora leaf spot conditions but also when the disease is not a factor.

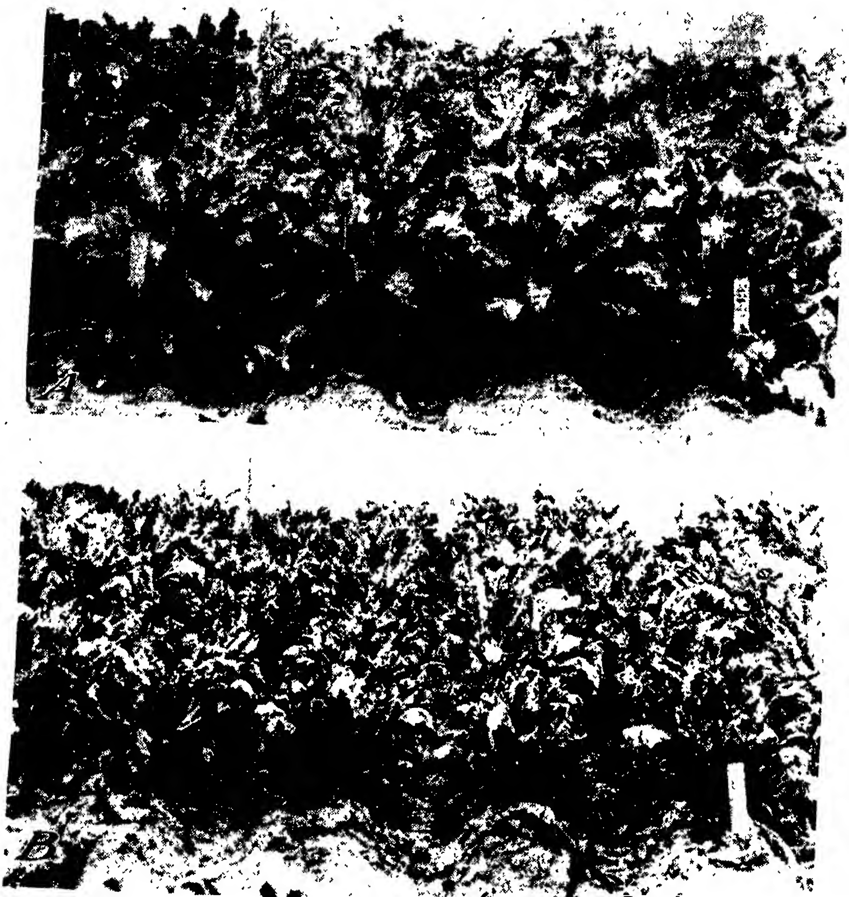

FIGURE 4.—Comparison of inbred strains under conditions of Cercospora leaf-spot epidemic: *A*, Highly resistant strain; *B*, very susceptible strain. Outer leaves of susceptible strain are killed, and remaining leaves are blighting badly.

In securing these resistant inbred lines, use has been made of the results painstakingly secured by W. W. Tracy, Jr. Beginning in 1915, he carried on a series of inbreedings with sugar beets for the purpose of isolating as many types as possible from the complex. Continued until 1929, Tracy's work gave source material from which strains outstanding in resistance were chosen. Selections were also made from the Leaf Spot Resistant variety developed by Skuderna.

Table 7 (p. 656) lists outstanding inbred lines that have come from this research. In all cases, these inbred lines have been increased in isolated plots to secure supplies of seed for use in large-scale production when the results of intensive tests determine which combinations of lines are the most desirable.

The first large-scale use of leaf-spot-resistant lines will be possible in 1937 with two synthetic varieties at present known by their field designations, accession 217 and accession 220. Using five inbred lines 40299–0 (*a*), 5–734–0 (*b*), 5–297–0 (*c*), 40293–0 (*d*), 5–735–0 (*e*),[5] hybrids have been made by pairing $a \times b$, $b \times c$, $d \times e$, in three isolated fields. The seed from these fields has been mixed in approximately equal proportions to supply the stock seed for planting commercial seed fields. Accession 220 contains the same inbred lines as accession 217, but the method of incorporating the lines in the final synthetic variety is slightly different. Seed will be produced in the summer of 1936 on approximately 150 acres. The seed stocks of the inbred lines are being maintained, and from these, new poolings can be made to continue the production of the synthetic varieties as long as their performance justifies it.

In the plan followed, preliminary tests of the varieties should be far enough along before the large-scale commercial increases (second commercial increases) are made to give information as to the performance to be expected from the synthetic variety.

OTHER BEET-BREEDING ACTIVITIES IN THE UNITED STATES AND CANADA

Cooperative work of the Michigan Agricultural Experiment Station with the United States Department of Agriculture is closely following the plan of securing pure lines by inbreeding, testing combinations of these lines for effects of heterosis or hybrid vigor, and testing the strains so produced for performance under humid-area conditions. These plans look toward laying the foundation for the production of a stable, improved variety of sugar beets that can be reproduced again and again as needed. A report from this experimental work in 1935 indicates that many inbred strains are being compared, 5 of them having been inbred for 6 generations, 90 for 5, 112 for 4, and 44 for 3 generations. These strains, which were started from selected roots taken from commercial brands, are beginning to become uniform in appearance with continued inbreeding, and crossing between inbred trains is projected.

Breeding investigations of the Department of Agriculture in cooperation with the Colorado Agricultural Experiment Station in Colorado have been concerned with the technique to be employed in securing isolation (*7*); inheritance of certain genetic characters; and the development of inbred lines suitable for studying the inheritance of quantitative characters such as sucrose percentage and size and shape of root. Selections have been made for resistance to drought and cold. Tests of progenies from these selections have shown that cold resistance in the seedling stage is a hereditary character and capable of purification. Inbred lines from red garden beets and from sugar and red garden beet crosses are being carried for use in genetic investigations.

The California Agricultural Experiment Station, Davis, Calif., has conducted sugar-beet breeding investigations chiefly for curly top

[5] See table 7.

resistance and to secure nonbolting lines. The work was begun in 1928 when some curly-top-resistant material was turned over to the station by the Spreckels Sugar Co. This material and the results obtained with it have been described (*12*). The work with the resistant variety was continued by the experiment station on a very limited scale until 1933 and then was practically dropped because it seemed inadvisable to duplicate similar work being done by the Department of Agriculture. None of the seed developed in Davis was ready for commercial distribution, but some of it, considered valuable for hybridization, was sent to the Federal station at Salt Lake City, Utah.

Breeding for nonbolting was begun in 1929 on a small scale and results do not yet permit any definite conclusions. The first generation of the beets selected for nonbolting showed marked decrease in the tendency to bolt, but in the second generation certain lines showed a high degree of bolting while others maintained a lower degree.

In cooperation with the Department of Agriculture, breeding investigations are being conducted to attempt to secure strains of beets resistant to root rot caused by *Sclerotium rolfsii*. This work, begun in 1932 with beets selected from badly affected fields, shows some promise that resistant material may be obtained.

Breeding Work of Commercial Organizations

The Canada & Dominion Sugar Co., Chatham, Ontario, has conducted mass-selection work since 1912 to produce an improved strain. Several hundred pounds of this seed were used for steckling production in 1934. The strain is known as Home Grown (Canada). Other lines are being developed.

The research department of the American Crystal Sugar Co.—formerly the American Beet Sugar Co.—Rocky Ford, Colo., conducted mass-selection work from 1920 to 1929 and developed the Flat Foliage variety, a high-sugar type, for use under leaf spot conditions prevalent in southeastern Colorado. The strain is used on a considerable scale, seed being produced annually from elite stocks.

By repeated selections, beginning with a beet selected under epidemic conditions, a strain was produced designated as Leaf Spot Resistant. This strain, which possesses high leaf spot resistance, was too low in sucrose percentage to be used commercially. It has been a valuable source of inbred strains possessing high resistance to Cercospora leaf spot.

The research division of the Great Western Sugar Co., Denver, Colo., has conducted extensive beet-breeding operations since 1915, growing many hundreds of acres of beet seed annually from its elite stocks. Until recently the methods followed have been similar to those used in European beet breeding. Announcement has been made of the development, by "family" or tested-progeny breeding, of a type tolerant to Cercospora leaf spot (*10*). This variety is being widely used in company operations under the name Great Western.

The Amalgamated Sugar Co., Ogden, Utah, has conducted selection work for curly top resistance and developed a variety called 600, which possesses strong curly top resistance, by crossing a hybrid, P 19 (Spreckels Sugar Co.)×905a2 (Carsner), with primary selections from commercial fields. In 1936, a considerable quantity of this variety will be used in commercial acreages.

New Industry Based on Plant Breeding—Production of Sugar-Beet Seed in the United States

AS HAS been stated, the United States has imported the greater part of its sugar-beet seed supply except during the World War period. The costs of seed production under the conventional system in which stecklings are siloed over winter and replanted in a seed field were much greater in the United States than abroad. In the absence of specially adapted varieties in the United States, the urge for domestic seed production was in part lacking. Certain companies

FIGURE 5.—A field near Las Cruces, N. Mex., planted for sugar-beet seed production. (Planted Sept. 4; photographed Oct. 6, 1932, by H. A. Elcock.) It has proved to be possible to overwinter plants in the field, which eliminates expensive handling costs.

having breeding work in progress have maintained seed production by the conventional method. The data as to seed imported from year to year into the United States have been compiled from United States Department of Commerce reports (*4*). In general, about 15,000,000 pounds were brought in annually in the period from 1920 to 1933. American production prior to 1932 furnished a very small percentage of the sugar-beet seed used.

Cooperative investigations by the New Mexico Agricultural Experiment Station, State College, N. Mex., and the United States Department of Agriculture demonstrated the possibility of producing sugar-beet seed under the mild winter conditions in the southwestern United States by overwintering the plants in the field. This method eliminates the expensive handling costs involved in lifting stecklings

FIGURE 6.—General view of seed field at ripening time: Las Cruces, N. Mex. (Photographed by H. A. Elcock.) These experiments in New Mexico are part of the effort to establish a beet-seed industry in the United States to meet specific American needs.

in the fall, siloing, and replanting. The losses of stecklings in the silo due to freezing and rotting are also avoided.[6]

In the method as developed, some of the steps of which are illustrated in figures 5, 6, and 7, beet seed is planted in early September, exactly as one would plant sugar beets for ordinary crop production. The beets are left unthinned and given enough irrigation to maintain them alive over winter. The next summer, seed is produced on the overwintered plants. Cultural operations, except hand hoeing which may be necessary in weedy or grassy fields, are carried on by machine. The seed may be cut by machine (mower or reaper) or by hand. The seedstalks are shocked in cocks to dry, and the seed is threshed, either from the field or from stacks, with standard threshing equipment adapted for this purpose. By care in giving light irrigations at weekly intervals during the setting period, seed of high viability has been obtained. In certain years, clean seed, graded to remove the small, immature seed, has shown from 85 to 90 percent germination.

The development of the sugar-beet seed industry in New Mexico, Utah, Nevada, California, and recently in Arizona, has been rapid. For the years 1933, 1934, and 1935 the seed produced by this method was largely the U. S. 1 and U. S. 34 varieties.[7] In the 3 years mentioned 5,283,000 pounds of the curly-top-resistant varieties were

[6] Because it illustrates the turning to advantage of some otherwise fruitless efforts, the history of this important development has unusual interest. Experiments begun in 1922 by C. O. Townsend and Fabian Garcia with a view to determining the best time to plant for beet production led to observations encouraging the belief that seed production by overwintering the plants in the field was practicable. The experiments originally planned demonstrated the futility of attempting to grew beets for the factory in that area on account of unusually severe curly top. However, the tests served a useful purpose because fall plantings were included and these proved the clue to the seed-production method. Several investigators contributed to the method, including G. R. Quesenberry and W. T. Conway, who directed attention to the fact that September plantings uniformly produced seed stalks. E. W. Brandes, who succeeded Dr. Townsend in charge of the Division of Sugar Plant Investigations, observing that, in great contrast to the earlier plantings, the September plantings were singularly free from curly top and therefore definitely more promising, shifted the local interest of the Division to seed production exclusively. Under the direction of J. C. Overpeck the cooperative seed experiments were vigorously pushed, with results that vindicated belief in the new industry.

[7] See tables 2 and 4, pp. 652 and 653.

FIGURE 7.—Threshing sugar-beet seed at State College, N Mex., August 20, 1929. The shocks are hauled on sleds to the threshing machine. Regular threshing equipment fitted with suitable screens and shakers is used. (Photograph by H. A. Elcock.)

produced on 2,400 acres, the average yield per acre being 2,200 pounds.

In the fall of 1934 nearly 500 additional acres were planted with American varieties other than the curly-top-resistant sorts, for use outside of the curly top area. The indications for 1936 are that on a total of 5,350 acres planted in the fall of 1935 the United States will produce approximately 30 percent or more of its 1937 seed requirements. Details of this interesting development are given in the literature cited (*11*, *19*).

Domestic seed production and breeding are definitely interlocking activities. Prompt introduction of improved varieties can best be accomplished if facilities are available for the economical production of seed true to designation and of good quality. Domestic seed production requires a constant source of elite seed to use for increase. We may expect steady expansion of domestic seed production and with it greater developments in breeding to provide improved and tested supplies of foundation stocks.

Recent Advances in Genetics Promise Further Possibilities for the Breeder

AS IS generally recognized, the sugar beet presents certain difficulties in genetical investigations. It is commonly biennial and normally sets seed as a result of wind or insect pollination. It is readily out-pollinated by red beet, chard, or mangel-wurzel. The

small, perfect flowers, borne in a common cluster of from one to five or more, make hand pollination extremely difficult, especially as the progressive opening of the flowers on the seedstalk increases the likelihood of contamination. These factors make breeding experiments with the sugar beet time-consuming and arduous.

Earlier work depended largely on space isolation to secure selfing of plants. Many investigators have reported securing set of seed under cages of cloth or of glass. The cloth used for cages was believed to be close-meshed enough to prevent entry of foreign pollen. Successful results have also been obtained by use of parchment or kraft paper bags. Extensive tests of this method have been reported by Brewbaker (*7*), who refers to earlier use of the bagging method with beets. Other advances in technique may be noted, such as the use of vegetative clons of beet roots to continue the stock and to permit hybridizing plants with a comparable genetic make-up. Fruiting has been controlled in greenhouse plantings by means of temperature control and the use of artificial light to increase length of day. By the use of the bagging technique in these greenhouse plantings, selfing of individuals and controlled crosses have been readily secured. Vernalization [8] of germinating seed has been used to induce early fruiting in greenhouse tests and has also afforded a reliable means of judging tendencies toward early bolting. These methods are in common use at the United States Sugar Plant Field Station at Salt Lake City, Utah, and have been of distinct service in genetic investigations.

With any type of isolation the possibility of undesired crossing must be recognized. Space isolation cannot be adequate to assure absence of wind-blown or insect-carried pollen in all cases. Sugar-beet pollen has been caught by airplanes high in the air, and preliminary tests indicate that pollen grains caught at elevations of 1,000 feet apparently were viable. The caging of plants requires meticulous care that the cages be set before any flowers open. The bagging requires faithful examination to assure that no flowers on the branch have opened.

Several investigators have reported the existence of sterile, partially sterile, and self-sterile individuals in the sugar-beet complex. Inbreeding obviously sorts out self-sterile individuals at once, so that inbreeding is restricted to the strains that produce seed under these conditions (*15*). There is a pressing need in sugar-beet breeding for more information on the self-sterility and self-fertility factors. Improvement of breeding methods and efficient utilization of the material now available is dependent on the findings that may come from such research.

A similar statement might be made concerning other heritable characters of the sugar beet. Only a start has been made on the problem involved in color inheritance, the early investigations by Lindhard and Iverson (*16*) having given information on the characters involved in red, yellow, and white coloration, with a hint at linkages. Recently Keller (*14*) has listed nine color characters and given evidence as to their inheritance. In this study the cross-over value between the factor *R* for red color of the hypocotyl (the portion of the stem below the first seed leaves) and the basic pigment factor *Y*

[8] Vernalization as employed with sugar beets denotes exposure of germinating seeds to temperatures near the freezing point for approximately 1 month. The effects of such treatment are the shortening of the vegetative period and the prompt occurrence of the fruiting phase.

was found to be approximately 7.5 percent. Evidence has been secured by F. A. Abegg and is now in course of publication on a linkage relation between annualism (bolting the first year) and red hypocotyl color, *R*. A linkage between a major factor for curly top resistance and this hypocotyl color has also been shown. These two studies give the first definite information on a linkage group in sugar beets[9] (*13*). Advances in our knowledge in this direction have prompt and valuable applications. Characters such as color are of great service to the plant breeder because they may serve as markers to identify a hybrid and permit its separation in experimental crossings.

The reports of recent work from foreign laboratories are extremely interesting. Russian investigators and those in other countries are engaged in a thorough cytological study of the chromosomes in the sugar beet and of chromosome variation. To the previous knowledge of the chromosome numbers of *Beta vulgaris*, *B. maritima*, and *B. trigyna* has been added the information for various other wild species. It is probably of considerable significance that the $2n$ chromosome number in all species of *Beta* studied, except *trigyna*, is 18. *B. trigyna* has 36 as the $2n$ number, and a strain of this species with a variant number has been found in the Crimea. The Russian workers also report polyploidy as occurring and state that the polyploid individuals show increased value for use.[10]

EXPLORING NEW SOURCES OF GENES

With the renewed interest in such scientific attacks on sugar-beet genetics, the problem of the gene content of the beet becomes of salient importance. As has been brought out earlier, the sugar beet as we have it today, with variations that seem so numerous as to confound analysis, may have lost important factors in the course of its development or there may be exceedingly valuable new genes which might be introduced (*5*). It is clear that the source of new genes must be outside of the sugar-beet brands now available, because these seem largely, if not entirely, to trace back to a common source. Two avenues seem open in this experimental exploration. The cultivated plants with which the beet readily hybridizes—the red garden beet, the Swiss chard, and the mangel-wurzel—may be sources of new factors for the geneticist. Savitsky,[11] for example, has produced evidence concerning inheritance of quantitative characters. He believes that sucrose production may be governed by four factors which he denominates *SS SS SS SS*, of which three exist in the sugar beet and a fourth in the mangold (Swiss chard). Similarly, he suggests that factors which govern size may reside in the mangel-wurzel, which, while it can make no contribution to the sucrose factors, may contribute size factors to the sugar beet.

The other source of new genes may be the wild species of *Beta*. It has commonly been accepted that *B. maritima* was the wild progenitor of the sugar beet. The ready crossing of *B. maritima* with all types of

[9] ABEGG, F. A. A GENETIC FACTOR FOR THE ANNUAL HABIT IN BEETS (BETA VULGARIS L.) AND LINKAGE RELATIONSHIP. (In preparation.)

[10] For a brief resume of Russian investigations, the summary by Kagan in the Institut International de Recherches Betteravières for 1934 may be consulted. More complete accounts have been published in the various reports from the Sugar Research Institute, Kiev, Union of Soviet Socialist Republics.

[11] See footnote [10], above.

beets, the similarity of chromosome numbers and the apparent (not explored) identity in hereditary characters gave color to this assumption. Recently the studies of Zosimovich (*29*) on the species of *Beta* occurring in Transcaucasia and Asia Minor have focussed attention on this area as one of the main centers of formation of the genus.

Table 8 (p. 656) gives a list of the wild species of the genus *Beta* and the general geographic areas in which they are found. For additional information the monograph by Ulbrich (*25*) may be consulted. Those which are known to cross with sugar beet are indicated in the table. During the summer of 1935, seeds of many of these species were secured for use in experimental work in the United States.

HYBRIDIZATION OF INBRED LINES

Of exceeding interest in practical breeding work and in genetic investigations is the reaction which follows hybridization. On the basis of the results in corn investigations and certain general observations, such as the response when *Beta vulgaris* and *B. maritima* are crossed (*9*), heterosis effects have been predicated as occurring in the F_1 or first hybrid generation of sugar beets. Evidence secured with 22 inbred lines developed in the course of the Cercospora leaf spot investigations [12] clearly indicates the significance of heterosis phenomena in sugar beets. The general average for the 41 hybrids produced by various combinations of these inbred lines showed the yield of the hybrids to be 43 percent greater than the mean yield of both parents, and 39.5 percent greater than the yield of the commercial variety used as a check. Considering individual results from the replicated tests, the lowest hybrid yielded 9.8 percent more than the commercial check, and the highest, 65.7 percent more. No hybrid lot was significantly lower in yield than the check, 12 of the 41 tested were not significantly different, and 29 were significantly better. The comparisons based on mean yields of both parents are approximately the same as those given in terms of the commercial brand. Sucrose percentages in hybrids, with a few exceptions, seemed to approach the mean of the parents chosen.

The placing of heterosis in sugar beets on a factual basis is extremely significant in its bearings on the future breeding program. Since strong responses in yield came in a fairly large percentage of the crosses, and the yields of the hybrids were often strikingly better than the mean of the parents, and often exceeded that of the commercial brand used as a check, it may be expected that beet-breeding methods will seek to utilize inbred lines in purposeful combinations as has been profitably done with corn.

Not all hybridizations result in a more vigorous F_1 generation. Hence the problem requires the development of many desirable inbred lines and the determination of their qualities and behavior in various hybrid combinations.

Since the production of inbred strains seems to be desirable in breeding efforts, a direct and logical corollary of the findings made on heterosis may be pointed out as a guide in such attempts. Drawing from our experience, it may be stated that mere continuous selfing of plants, especially on the limited scale possible with sugar beets, does not necessarily lead to the results commonly connoted in the term "inbreeding." In selection work, it is entirely natural to choose

[12] From unpublished data obtained in investigations by Stewart, Lavis, and Coons, U. S. Department of Agriculture.

sugar beets on the basis of size and sucrose percentage. Since the sugar beets with which breeding operations would start are essentially hybrids, and the breeding plan hitherto followed seeks to insure this, the large beet in the field most likely is large because of its hybrid nature. As this beet is inbred, the large beets in its progeny would be the ones most nearly reproducing the parental F_1 or hybrid condition. Hence it is conceivable that continued inbreeding might deal always with the heterozygous portions of the progeny and make little progress, the material under study never reaching a stage of homozygosity such that there could be rapid progress in purification. As one reads various statements about the selection of beets on the basis of size and sucrose content, it is clear that the potency of heterosis, although accepted in theory, has often been disregarded in practice.

The sugar-beet breeding projects of the Department of Agriculture, as shown in preceding sections, have followed two lines of development: (1) For immediate production of varieties showing adaptation to the disease factor or some other special condition, the standard selection methods have been followed, and when desirable varieties have been obtained in this way, these have been made available for general use, and (2) increasing emphasis is being placed on the development of desirable inbred lines as the basis for beet improvement. The securing and testing of such lines and the determination, among companion lines, of those that are compatible and complementary require much effort. The process is slower in attaining desired results than is the case with certain other plants.

As vigor seems to become less with continued inbreeding—although this may not invariably be the case—the task in such a problem as breeding for Cercospora leaf spot resistance is complicated by the necessity of finding many lines instead of a single one. As lines are developed, one is always confronted with the fact that the sugar beet is a highly specialized crop, and inbred lines must be severely culled to retain only those of satisfactory commercial quality.

Given inbred lines suitable in quality and stabilized, for example, for leaf spot resistance, there is still the problem of securing the desired intercrossing between lines on a commercial scale. In any large-scale attempts at hybridization, a certain percentage of the plants are the result of self-fertilization, which perpetuates the original inbred lines. Such selfed plants probably will yield less than those arising from cross pollination between the lines paired. Various methods of counteracting the effects of selfing in the development of the final product are under test. One method used is the scheme described in connection with the two synthetic varieties being increased for use in leaf spot areas.

These steps in the development of a technique in beet breeding may take a considerable time to perfect. Genetic research is now giving information that can be applied to the very practical problem of securing improved varieties for the farmer. The performance of such hybrid combinations as have been made so far is exceedingly encouraging. Once the desired combinations are found, the results should be noteworthy. Since the foundation inbred lines may be maintained by proper isolation, or made more homozygous by additional generations of inbreeding, the recreating of the desired combination may readily be accomplished. The increased efficiency possible with this simplification of the work of producing foundation or elite

stocks of sugar-beet varieties will in itself do much to offset the expense and effort necessary to secure the basic inbred lines with which to work.

The interest that is being aroused in the whole subject of sugar-beet improvement is extremely encouraging. As the problems are understood and the needs are properly visualized, there is little doubt that the American industry will take up the challenge.

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Appendix

TABLE 1.—*Record of seed production and utilization of the curly-top resistant variety U. S. 1, 1929-35*

Year of seed production	Description	Place	Area planted for seed production	Quantity	Commercial beet acreage planted in curly top area [1]
			Acres	*Pounds*	
1929	Original or foundation stock.[2]	Twin Falls, Idaho		70-100	
1930	First direct multiplication	State College, N. Mex. St. George, Utah Beaumont, Calif.		972 600 600	Experimental plantings.
1931	Second direct multiplication	State College, N. Mex Hemet, Calif		1,657 1,500	Experimental and grower-test plantings.
1932	Second direct multiplication (called also first commercial increase)[3]	Mesilla Valley, N. Mex. St. George, Utah Hemet, Calif.	5 5.1 5	8,774 8,324 5,500	Do.
1933	Third direct multiplication (called also second commercial increase)	Mesilla Valley, N. Mex. St. George, Utah district [4] Hemet, Calif.	145 240.6 50	390,000 341,308 146,091	200 acres.
1934	Third direct multiplication (called also second commercial increase)	Mesilla Valley, N. Mex. St. George, Utah district [4] Hemet, Calif. Pecos Valley, N. Mex.	365 386.5 62.5 1.8	823,971 910,629 140,607 4,671	35,000 acres.
1935					102,803 acres.

[1] Estimated, seed used in year shown was mostly produced the preceding season.
[2] Carsner (8).
[3] Seed produced by commercial companies.
[4] Includes acreage in Moapa Valley, Nev.

TABLE 2.—*Record of seed production and utilization of the curly-top-resistant variety U. S. 33, 1932-36*

Year of seed production	Description	Place	Area planted for seed production	Quantity	Commercial beet acreage planted in curly top area
			Acres	*Pounds*	
1932	Reselection from U. S. 1 (selection based on refractometer and polariscope readings, 100 roots chosen).	Twin Falls, Idaho and Salt Lake City, Utah.		2.5	
1933	Seed increase	Salt Lake City, Utah		250	
1934	First multiplication.	State College, N. Mex.		5,640	Experimental acreage.
1935	Second multiplication (called also first commercial increase)	State College, N. Mex. Pecos Valley, N. Mex St. George, Utah Hemet, Calif	5 10 32 12	10,000 3,042 57,601 30,965	Do.
1936	Third multiplication (called also second commercial increase)	Mesilla Valley, N. Mex. Salt River Valley, Ariz. Moapa Valley, Nev Hemet, Calif.	100 50 116 371		Do.

TABLE 3.—*Record of seed production and utilization of the curly-top-resistant variety, U. S. 34*

Year of seed production	Description	Place	Area planted for seed production	Quantity	Commercial beet acreage planted in curly top area.
			Acres	*Pounds*	
1932	Reselection from U. S. 1 (1,000 roots chosen from 10,000 picked for curly top resistance, selection based on refractometer reading).	Twin Falls, Idaho, and Salt Lake City, Utah.		57	
1933	First multiplication	State College, N. Mex	1.38	857	
1934	Second multiplication (called also first commercial increase).	State College, N. Mex Mesilla Valley, N. Mex St. George, Utah Hemet, Calif.	5 10 34.25 5	10,770 22,496 27,411 18,608	Experimental acreage.
1935	Third multiplication (called also second commercial increase).	Mesilla Valley, N. Mex St. George, Utah Hemet, Calif	156 427 395	307,746 835,129 1,281,881	Do.
1936	do	Mesilla Valley, N. Mex Salt River Valley, Ariz St. George, Utah Hemet, Calif	700 50 471 242		90,000-100,000 acres.[1]

[1] Estimated.

TABLE 4.—*Source list of material available in 1936 as possible foundation stocks to replace U. S. 34*

[List given is a partial one and subject to drastic revision following evaluation tests]

Designation	Source	By whom selected	Years tested	Outstanding character	Suggested utilization
			Number		
U. S. 12	U. S. 1, "33 best of 1932."	F. V. Owen and F. A. Abegg.	2	Curly top resistance; general performance.	Extensive agronomic evaluation tests.
U. S. 13	5001 (Carsner and Pack) California increase.	do	2	Curly top resistance; nonbolting; good yield under curly top conditions.	First commercial increase.
U. S. 14	5001 (Carsner and Pack) Utah increase.	do	2	do	Do.
U. S. 15	Commercial variety (Pioneer).	G. H. Coons, Dewey Stewart, and H. A. Elcock.	5	Curly top resistance; nonbolting.	Do.
2167	U. S. 1	F. V. Owen and F. A. Abegg.	2	Curly top resistance; nonbolting and high sugar.	Seed supply being increased.
550	Hybrid, U. S. 1 selection × "600" (Amalgamated Sugar Co.).	F. V. Owen, F. A. Abegg, R. H. Cottrell, and V. Jensen.	1	Curly top resistance; extremely nonbolting.	Selection and increase.

TABLE 5.—*Sugar-beet breeding in the United States and Canada, 1885–1936*

Period	By whom carried on	Place	Methods employed	Purpose	Varieties produced	Present staff
1885–95	U. S. Department of Agriculture (H. W. Wiley).	Schuyler, Nebr.	Mass selection	Improvement		
1888–1917	South Dakota Agricultural Experiment Station (J. A. Shepherd).	Fargo, S. Dak.	do	do	South Dakota 1 (not introduced commercially).	
1910–22	U. S. Department of Agriculture (C. O. Townsend).	U. S. Department of Agriculture, Utah, California.	do	(1) Curly-top resistance; (2) single-germ seed.		
1915 to July 1, 1936	Great Western Sugar Co.	Longmont, Colo.	Mass selection from mother lines.	Improvement; leaf spot resistance.	Great Western (used commercially).	H. A. Dahlberg, Asa Maxson.
1920 to July 1, 1936	American Crystal Sugar Co.	Rocky Ford, Colo.	Mass selection from mother-line breeding.	High sugar under leaf spot conditions; leaf spot resistance.	Flat Foliage (used commercially); Leaf Spot Resistant.	A. W. Skuderna, 1920–29; 1935–.
1912 to July 1, 1936	Canada & Dominion Sugar Co. (Henry Stokes).	Chatham, Ontario	Mass selection and mother-line breeding.	Improvement	Home grown (Canadian) (to be used commercially 1936). Stokes (Canadian grown).	Henry Stokes, H. D. Brown.
1919–28	Spreckels Sugar Co.	Spreckels, Calif.	Mass selection	Curly top resistance	P 19 (not used commercially).	
1929 to July 1, 1936	California Agricultural Experiment Station and U. S. Department of Agriculture, cooperative.	Davis, Calif.	Mass selection and pure-line breeding.	(1) Nonbolting strains; (2) resistance (*Sclerotium rolfsii* resistance).		W. W. Robbins, Katherine Esau, F. G. Larmer.
1915 to July 1, 1936	U. S. Department of Agriculture.	Arlington Experiment Farm, Va.; Fort Collins, Colo.; Rocky Ford, Colo.; and State College, N. Mex.	Pure-line breeding	Leaf spot resistance; curly top resistance; genetic investigations (cooperative with Colorado Agricultural Experiment Station).	Crosses of resistant inbred lines under test.	G. H. Coons, Dewey Stewart, John O. Gaskill, H. W. Bockstahler (leaf spot investigations), H. E. Brewbaker, G. W. Deming (genetic investigations).
1918 to July 1, 1936	do	Riverside, Calif., Salt Lake City, Utah, and Twin Falls, Idaho.	Mass selection and pure-line breeding.	Curly top resistance; genetic investigations; nematode resistance.	U. S. 1, U. S. 33, U. S. 34 (used commercially) in bred lines and selections under tests.	Eubanks Carsner, F. V. Owen, F. A. Abegg.
1922 to July 1, 1936	Michigan Agricultural Experiment Station and U. S. Department of Agriculture,, cooperative.	East Lansing, Mich.	Pure-line breeding	Improvement	Various inbred lines being tested in various combinations	E. E. Down, H. L. Kohls
1927 to July 1, 1936	Amalgamated Sugar Co.	Ogden, Utah	Mass selection	Curly top resistance	Amalgamated Sugar Co. "600" (used commercially).	R. H. Cottrell, V. Jensen.
1930 to Sept. 1935	Minnesota Agricultural Experiment Station and U. S. Department of Agriculture, cooperative.		Pure-line breeding	Genetic investigations		F. R. Immer.

Table 6.—*Showing, from year to year the possible succession of operations in the improvement of the sugar beet* [1]

First year, fall	Second year	Third year	Fourth year	Fifth year	Sixth year	Seventh year	Eighth year
Choice of: Cl. I Super-elite (roots).	Cl. I Super-elite (seed).	Roots	1st multipl. (seed)	Yield test (roots)	Stecklings (roots)	Selected seed (sale)	
Cl. I Good elite (roots).	Cl. I Good elite (seed).	do	do	Reserve (seed)	do	do	
Cl. I Elite (roots).	Cl. I Elite (seed)	do	do	do	do	do	
Cl. II–III (roots).	Cl. II–III (seed)	do	do	$\frac{1}{2}$ stecklings (roots)	Commercial seed (sale).	Commercial seed (sale).	
				$\frac{1}{2}$ reserve (seed)	Stecklings (roots)		
	New choice of: Cl. I Super-elite (roots).	Cl. I Super-elite (seed).	Roots	1st multipl. (seed)	Yield test (roots)	Stecklings (roots)	Selection seed (sale).
	Cl. I Good elite (roots).	Cl. I Good elite (seed).	do	do	Reserve (seed)	do	Do.
	Cl. I Elite (roots)	Cl. I Elite (seed)	do	do	do	do	Do.
	Cl. II–III (roots)	Cl. II–III (seed)	do	do	$\frac{1}{2}$ stecklings (roots)	Commercial seed (sale).	
					$\frac{1}{2}$ reserve	Stecklings (roots)	Commercial seed (sale).
		New choice of: Cl. I Super-elite (roots).	Cl. I Super-elite (seed).	Roots	1st multipl. (seed)	Yield test (roots)	Stecklings (roots).
		Cl. I Good elite (roots).	Cl. I Good elite (seed).	do	do	Reserve (seed)	Do.
		Cl. I Elite (roots).	Cl. I Elite (seed)	do	do	do	Do.
		Cl. II–III (roots)	Cl. II–III (seed)	do	do	$\frac{1}{2}$ stecklings (sale)	Commercial seed (sale).
						$\frac{1}{2}$ reserve (seed)	Stecklings (roots).
			New choice of: Cl. I Super-elite (roots). Cl. I Good elite (roots). Cl. I Elite (roots).	Cl. I Super-elite (seed). Cl. I Good elite (seed). Cl. I Elite (seed)	Etc.	Etc.	Etc.

[1] Copied from: "Improving the Sugar Beet", by V. Lathouwers. La Sucrerie Belge. Organe de la Société Générale des Fabricants de Sucre de Belgique et de la Société Technique et Chimique de Sucrerie de Belgique. Numéro du Centenaire. 50[e] Année (Translation by H. A. Kuyper.)

TABLE 7.—*Inbred lines of sugar beets starting from roots selected from commercial fields, produced by the Division of Sugar Plant Investigations in connection with breeding for leaf spot resistance*

Current designation	Generations: Selfed	Generations: Group increase	Years tested	Outstanding characters
	Number	*Number*	*Number*	
30296-0 10742-27	6	2	3	Cercospora leaf spot resistance.
40293-0 5483-29	6	4	4	Do.
40299-0 4588-25	5	5	6	Strong Cercospora leaf spot resistance; high sucrose percentage.
5-297-0 3444-29	5	5	4	Cercospora leaf spot resistance; very high sucrose percentage.
5-298-0 00475-0[1]	1	3	3	Strong Cercospora leaf spot resistance; high sucrose percentage.
5-532-0 4516-29	3	5	4	Strong Cercospora leaf spot resistance.
5-546-0 4874-29	4	5	4	Do.
5-550-0 1294-29	7	2	4	Cercospora leaf spot resistance
5-580-0 6571-29	6	4	4	Cercospora leaf spot resistance; very high sucrose percentage.
5-734-0 Acc. 215	6	4	4	Cercospora leaf spot resistance.
5-735-0 6484-29	6	4	4	Strong Cercospora leaf spot resistance.
5-801-0 5885-29	6	4	4	Cercospora leaf spot resistance.

[1] Selected from Leaf Spot Resistant variety (Skuderna).

TABLE 8.—*Wild* [1] *species of beets and their general geographic location*

Species	Geographical distribution	Hybridization with *B. vulgaris* reported by –
Beta maritima L.	Mediterranean and Atlantic coasts	Munerati, Vilmorin, Schneider, Coons.
Beta trigyna W. and K.	Slavonia, Crimea, Transcaucasia, Turkey, and eastward.	Tschermak, Schneider, Savitsky, *et al.*
Beta intermedia Bunge	Asia Minor and eastward	
Beta lomatogona F. and M.	do	
Beta procumbens Chr. Sm.	Canary Islands	Schneider.
Beta patellaris Moq.	Mediterranean coast	
Beta patula Soland	Madeira Islands	Rimpau (?).
Beta macrocarpa Guss.	Portugal, Canary Islands, etc.	
Beta macrorhiza Stev.	Transcaucasia and southward	
Beta nana Boiss. and Held.	Greece	
Beta atriplicifolia Rouy	Spain	
Beta webbiana Moq.	Canary Islands	

[1] The sugar beet, red garden beet, Swiss chard, and mangel-wurzel are commonly classified as varieties of *Beta vulgaris* L.

Plant Breeding and the Cotton Industry

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TO UNDERSTAND the contribution that breeding has made to the cotton industry it is necessary first to know something about the origin of the various existing types of cotton. Scientists engaged in this field seem agreed that there were probably two general centers of origin of the cotton plant, one in the Old World and one in the New World. It is the opinion of some investigators that there might have been two centers of origin in the Old World, Indochina and tropical Africa, and that in the New World cotton might have either originated independently in two regions—Mexico or Central America, and the foothills of the Andes Mountains of South America—or have developed along different lines in these two regions. The cultivated cottons of today seem to trace back to cottons grown in ancient times in one or another of these four world centers. Archeological specimens indicate very ancient usage of cotton in Mexico and in South America and indigenous species in the Old World furnish some evidence of the double origin in that hemisphere.

Recent studies on the relationship of cottons from different parts of the world indicate that the American and Asiatic cottons have remained distinct probably since their origin. They are still so incompatible that crossing between them is rare, and persisting fertile hybrids are unknown. The American cottons have 26 chromosomes and the Asiatic species only 13. There are many different types and a number of different species of both Old World and New World cottons, however, and all of the cultivated forms of New World origin seem to cross readily with each other, although those that originated in South America are genetically quite different in many respects from those more recently introduced from Mexico. While the three types of cotton now grown in this country—sea island, American-Egyptian, and upland—are all probably of American origin, it would seem that the sea island and the American-Egyptian originally came from South America, and that all of the upland varieties either came originally from Mexico or at some time in the past arose from crosses of Mexican and South American species. Hybridization of North and South American species especially may account for some of the upland long staple varieties.

The Kinds of Cotton, the Background of the Breeder's Work, and the Relation of Breeding to Present Economic Needs

COTTON breeders also seem agreed that practically all of the varieties grown today are of hybrid origin; that is, they are hybrids of the older varieties of the same species or of the more compatible species. Many of these hybrids probably arose from natural crosses in fields where several varieties were grown together or near each other. Occasionally interspecific crossing may have occurred in situations where more than one species was cultivated in close proximity. The history of the origin and development of these cottons is very meager. Probably the type with the most definitely known historical background is the sea island, introduced into this country in Georgia from the Bahama islands about 1785. The sea island cotton also offers a good illustration of what careful selection and breeding will do. While information as to the methods pursued by the early growers is fragmentary, the results they secured are quite evident.

In connection with the development of the sea island cotton industry it is possible that more than one species and no doubt several varieties were brought in during the early period at the end of the eighteenth century and the beginning of the nineteenth. From these introductions, the sea-island growers doubtless developed their own distinct varieties and strains, but no descriptive records were kept. These early breeders knew little of genetics or the science of plant breeding, but they were artists in knowing their plants. They sought practical ends and concentrated on the development of the long silky type of cotton that the English spinners of that time demanded. Their ideas were based on philosophical biology rather than on scientific biology, taxonomy, or genetics. They felt that environment had considerable effect in producing changes in plants but that heredity transcended all external influences, and that like did really beget like. With this philosophy as a guide, and expertness in observing, sorting, and selecting, they were equipped to build up a great enterprise through plant breeding. Among these growers a particular variety was considered the personal property of the originator and seed was not exchanged or sold unless something better was at hand. The result was the development of many special strains of the finest cotton the world has ever known. Sea island cotton production (fig. 1) was limited to the islands off the coast of South Carolina and Georgia and to a narrow strip of mainland near the coast. The cottons grown in the interior, on the mainland, were of an entirely different type and were designated as upland cottons.

As early as the seventeenth century there are records of the bringing in of cottons from many parts of the world for growing in the interior. These were grown entirely for domestic use, and apparently little attention was paid to the quality of the fiber or the productiveness of the plants. It was not until cotton mills began to develop

and industrial uses were found for cotton that the growers of upland cotton began to pay attention to yield and to some extent quality. Since the Old World and New World cottons are not known to hybridize under conditions of cultivation and all of the upland varieties now grown in this country are quite definitely of the American type, it seems evident that among all the cottons brought together from various parts of the world at different times, the ones that survived in the upland growing area have been entirely of American origin and probably all came from Mexico and Central America. The vast differences in climate and soil that obtain over the Cotton Belt undoubtedly brought about a kind of natural selection which eliminated many of the kinds that were tried, while others became adapted to the several conditions under which they were grown and selected over a period of years.

BEGINNING OF COMMERCIAL PRODUCTION, AND THE EFFECT OF THE BOLL WEEVIL

As a result of such adaptation and selective breeding, there were many different types of upland in existence when cotton first became important as a commercial crop after the middle of the eighteenth century. These represented different sections of the Cotton Belt. In the eastern end the smaller bolled, prolific cottons were predominant. These were characterized by green seed and softer fiber than was found later in the stock farther west, where the cottons had large bolls, coarse fiber, and white seed. It is possible that the eastern Cotton Belt group came originally from the more humid eastern portions of Central America and Mexico while the more recent western Cotton Belt group was introduced from the interior and drier sections of Mexico. The older or pre-boll-weevil upland long staple type belonged to the former group and apparently had the same origin, with the exception of possible hybridization in some cases with sea island.

However, before the present western end of the Cotton Belt was developed, cottons from the interior or drier sections of Mexico began to come into the eastern growing areas of the United States. These types, which were characterized by large white seed, large bolls, and hard fiber, later became predominant in the western end of the Cotton Belt and in much of the East. About the first recorded importation of this type was one made by Walter Burling, who brought cotton from Mexico City to Natchez, Miss., in 1806. This variety was introduced in South Carolina about 1816 and eventually became the parent of a large number of varieties in that part of the Cotton Belt. It is thought that soldiers returning from the Mexican War of 1846 to 1848 also brought back seeds of this type, which doubtless became foundation stock of the big-boll stormproof cotton of Texas and some other parts of the western area.

In the 1850's a large-boll white-seeded cotton was introduced into Georgia by a German immigrant whose brother sent the seed to him from Algeria. This cotton was of the Mexican big-boll sort and perhaps was of Mexican origin. The importation later became the foundation stock for Jones Improved, Truitt, Russell, Columbia, Keenan, Hartsville, Webber, and much of the later breeding lines of the Coker's Pedigreed Seed Co. Greenish or green seed, particularly in Truitt and Russell, doubtless came about through cross-pollination.

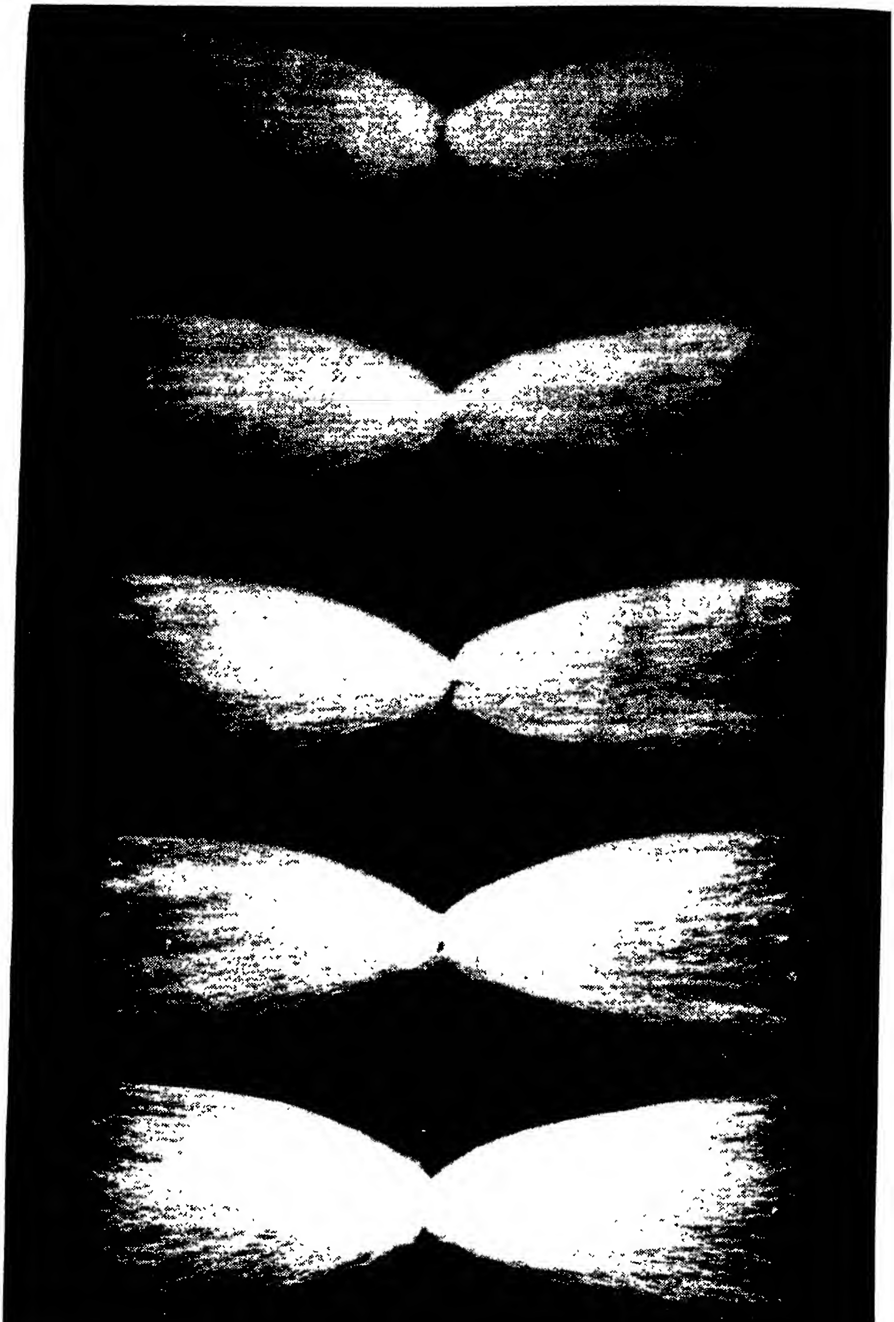

FIGURE 1.—Combed fibers on individual seeds of sea island cotton to show length of fiber and seed characteristics. Natural size.

During the first part of the present century, important stocks again were brought in from Mexico and Guatemala. Of these importations, Durango and Acala, the latter particularly have been notable introductions. These varieties respectively from western and southern Mexico and dry regions resemble the kinds previously brought in from the semiarid table land of that country. The kinds introduced from the humid eastern area of Guatemala—Kekchi, for example—had white seed and big bolls but were more like the old eastern Cotton Belt group of varieties in plant type and fiber texture. The Mexican sorts that have come from time to time directly across the Rio Grande have completely occupied the cotton area of the Southwest, Texas, Oklahoma, and much of Arkansas and Louisiana, and have invaded large portions of the eastern end of the belt. They have also been hybridized with the eastern varieties to such an extent that green-seeded varieties have practically disappeared. However, the small non-storm-resistant bolls and softer staple have prevailed as characteristics in many of the eastern varieties, probably because of selection under humid conditions. The large-boll hard-staple type seems to thrive better under dry conditions.

The spread of the boll weevil over the Cotton Belt at the beginning of the present century caused a widespread change in the types of cotton grown in the different regions. In the central part of the belt many large, vigorous-growing types of upland long-staple cotton had come to be grown very generally, and in much of the mid-South and Southeast the later maturing varieties of the shorter staple type had proved more productive and were of better staple than the recent short staple type. When the boll weevil struck these areas, however, it was no longer possible to grow late-maturing varieties. Varieties that had long been famous for high quality but were late in maturing were discarded and early short-staple cottons were substituted. These were usually inferior in quality but had developed early maturity and the determinate habit of growth—that is, they fruited rapidly instead of over a long season—from having been grown and selected on the northern rim of the Cotton Belt. There were only two criteria for these varieties—they must be early and productive.

In this way many excellent varieties of long-staple upland cotton and practically all of the better types of medium-staple were lost within a comparatively short time, to be replaced by the early, rapid-fruiting types brought in from the northern parts of the belt, wherever they were found. In the regions first occupied by the boll weevil some progress had already been made in developing early strains of the Texas Big Boll cottons, and by reselection these became adapted to a wide area west of the Mississippi River. In the eastern part of the belt breeders began breeding for earliness and rapid fruiting even before the boll weevil reached these sections. Trice in Tennessee, some of the Cleveland and Webber strains in South Carolina, Mexican and Cleveland strains in North Carolina, and Cook in Alabama, served in part to meet the situation when the boll weevil finally infested the Southeast.

RESULTS OF BREEDING FOR IMPROVED STAPLE

Considerable impetus was given to cotton breeding about this time, largely through the discovery that many of the early maturing cottons were of very inferior quality and that their production was

resulting in the loss of special markets which had been using the better cottons of pre-boll-weevil days for many years. The Department of Agriculture, several of the experiment stations, and such outstanding breeders as the Coker's Pedigreed Seed Co. and W. W. Wannamaker, of South Carolina, the Delta & Pine Land Co., of Mississippi, C. N. Nunn, of Oklahoma, John Gorham, A. M. Ferguson, Ed. Kasch, and R. L. Bennett, of Texas, and others began to develop rapid-fruiting early maturing varieties with better and more uniform staple. The foundation stock for these strains came quite largely from the western cottons, although in some cases the most outstanding developments resulted from hybridization between the eastern and western groups. Certain strains of Delfos, Missdel, Express, Wilds, Stoneville, Delta & Pine Land, Cleveland, Farm Relief, Acala, Rowden, Lone Star, Mebane Triumph, Mexican, etc., have developed to the point where seed is now available in all parts of the belt, and some of these are being used as foundation stock in one-variety communities for standardizing production of the American crop on a one-variety-community basis.

Another outstanding accomplishment of the cotton breeder in developing cottons of superior quality to meet a special situation resulted from the widespread occurrence of cotton wilt, first in the Southeast and later over the Coastal Plain section of the entire Cotton Belt. Wilt had been encountered on the sea islands in the early days and some of the breeders on the islands had developed resistant strains that were almost immune to the disease. Taking a lead from this work of the sea-island breeders, Orton and later Gilbert, Watson, McLendon, Lewis, and Tisdale, breeding cotton in different sections of the Southeast, developed strains highly resistant to the wilt fungus. Before these varieties became available there were large areas in the Southeast that could not safely be planted to cotton. Since their development, cotton can be grown without danger from the wilt hazard in every section of the South.

There is very definite statistical evidence of the improvement in the staple length of the American cotton crop as a result of the breeding work done during the past decade. The grade and staple statistics section of the Division of Cotton Marketing of the Bureau of Agricultural Economics made the first report of the grade and staple length of the cotton crop in 1928. In 1929, 58 percent of the crop was seven-eighths of an inch or less in length. There has been a rather consistent improvement in the staple length of the cotton crop since that time. In 1935, only 44 percent of the crop was as short as seven-eighths of an inch. The greatest improvement has taken place in the medium staples, $^{15}/_{16}$ to $1^{1}/_{16}$ inches, inclusive. In 1928, only 39 percent was of these lengths, whereas in 1935, this had increased to 50 percent of the crop. On the whole there has been an increase in the average staple length of the entire crop of approximately one-thirty-second of an inch. Interpreted in terms of premiums and discounts for staple prevailing in 1935, this has resulted in an increased value for the 1935 crop of about 80 cents a bale, a total of approximately $8,000,000. This improvement is due largely to the development by our leading breeders of more productive strains of cotton of better staple length and general quality and to the wider use of these better strains on a more standardized basis either by organized communities or by following Extension Service recommendations throughout the Cotton Belt.

FOREIGN COMPETITION CREATES A PRESSING NEED FOR MORE RAPID PROGRESS

While these definite accomplishments are comforting, conditions have arisen during the past 5 or 6 years which make it necessary to go forward in breeding and improvement work more rapidly than in the past. While the United States was improving the staple length and quality of its cotton, other countries were doing the same thing, many of them by importing seed of the best North American varieties and adapting these varieties to their own conditions. As some of the larger consuming countries, following a policy of national self-sufficiency, have attempted to produce the cotton they need or to purchase it from other countries with which they have a favorable trade balance, there has been a falling off in the demand for American cotton. It would seem that if these markets are to be regained, it will be necessary for the United States to produce better cotton than is grown anywhere else in the world. It seems necessary, therefore, not only to continue to improve the staple length and uniformity of American cotton but to breed into the new strains other quality factors that will enable the United States to compete successfully with other countries. Figure 2 shows boll, fiber, and seed of an improved upland variety of cotton.

Large areas in the United States are now producing cottons of very short staple that must compete with similar types from India and other countries. While some of these sections are more or less arid and do not seem to be adapted to the production of long-staple uplands, there is ample evidence to indicate definitely that cottons of longer and more uniform staple than they are now growing can be produced if breeders are given an opportunity to develop strains suited to local conditions.

There is also the question of improving the grade and quality of the crop by breeding strains better suited to harvesting methods practiced in different parts of the Cotton Belt. Mechanical harvesters for cotton are still in the experimental stage, but it is entirely possible that the mechanical picker might be made much more effective if types of cotton better adapted to this method of harvesting were bred. Some types are already in existence that might fit into such a development.

The intensive study now being made of 16 types of cotton grown at 14 widely separated localities throughout the main Cotton Belt is also taking into account the composition of cottonseed. It is known that the oil content of the seed of different varieties of cotton varies greatly, and there is some evidence that it is influenced by growth conditions. This opens up an important field of study, and there is every reason to believe that results might be obtained by the application of scientific breeding methods to the problem. The matter of breeding cottons of special staple length and character to meet different manufacturing needs is also a promising field for breeders. The United States annually imports approximately 100,000 bales or $10,000,000 worth of Egyptian cotton for the manufacture of certain finer fabrics. There is every reason to believe that the breeder could develop long-staple upland cottons or American-Egyptian types which might put this industry on a self-sufficient basis in the United States. While the development of rapid-fruiting, early maturing varieties has in a measure solved the boll weevil problem, there would seem to be an opportunity for further improvement by intensive study of plant and boll characters that might offer resistance to weevil attack.

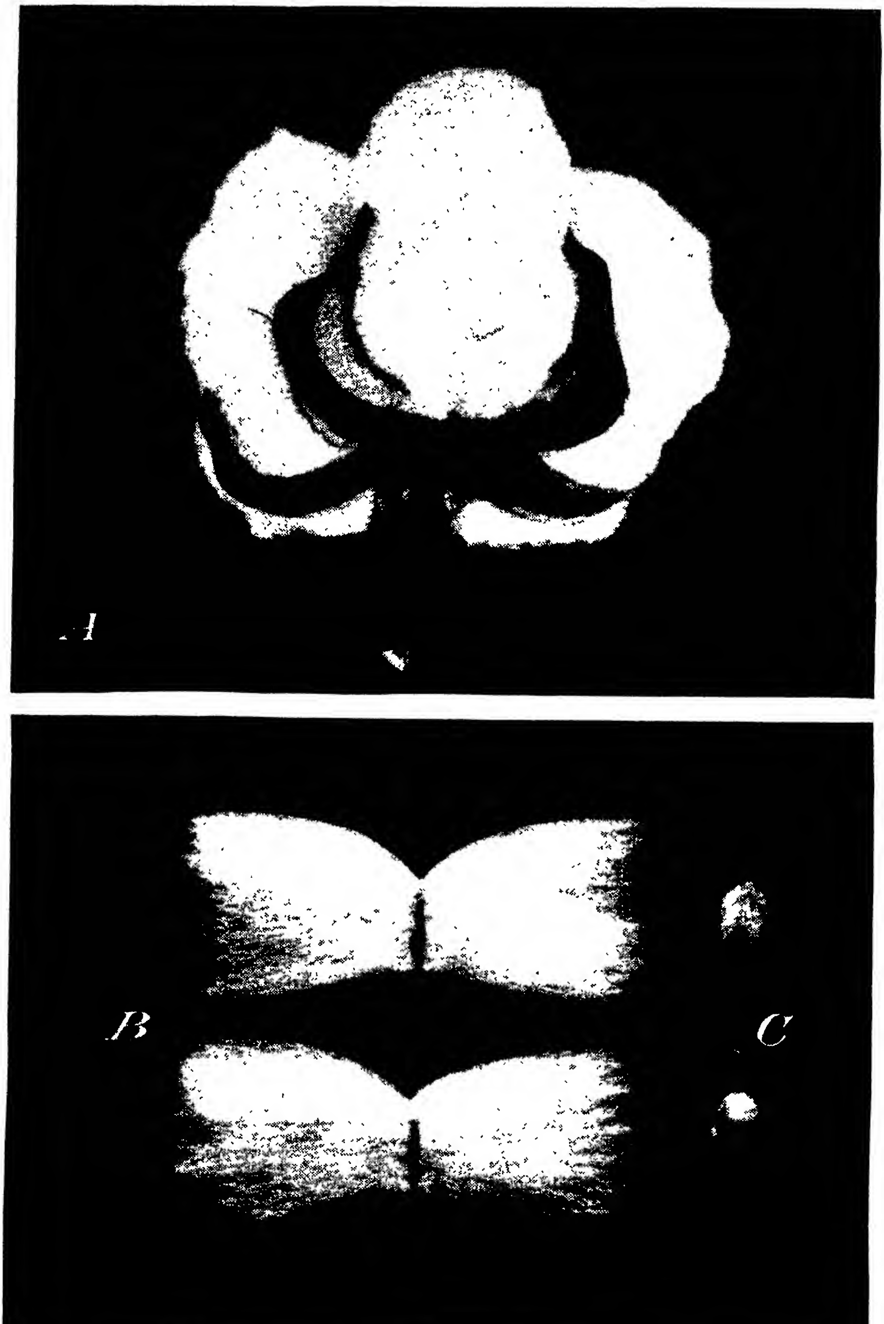

FIGURE 2.—An improved upland variety of cotton: *A*, Open cotton boll; *B*, combed fiber on the seeds; *C*, two seeds. Natural size.

In view of the many problems connected with developing and producing cottons better suited to domestic and foreign demand, more productive, and better adapted to the different climatic and soil conditions in various sections of the Cotton Belt, the Department in 1935 set up a preliminary cotton research program which includes a wide range of projects. As a background for some of the future research work, the series of regional variety experiments noted above is affording extensive studies of the influence of climate, soil, season, and other factors on the adaptation and production of these varieties, and on the quality and spinning value of the product. A genetic and breeding research program has been organized providing for fundamental genetic research or for breeding and improvement work

THE present foreign-trade situation is such that it is necessary for the United States to move forward more rapidly in breeding and improvement work and produce better cotton than is grown anywhere else in the world. The possibilities open to scientific breeding include the development of cotton of longer and more uniform staple length to meet local conditions in the Cotton Belt; the breeding of types better adapted to mechanical harvesting methods; the production of cottons of special staple lengths to meet special manufacturing needs—$10,000,000 worth of Egyptian cotton is now imported annually by manufacturers for this purpose; improvement in the oil content of cottonseed; and further improvement in resistance to the attacks of the boll weevil.

in each State across the belt from North Carolina to California. All of this work is in cooperation with the agricultural colleges and experiment stations and is closely coordinated with cotton work in the Bureau of Agricultural Economics, Bureau of Agricultural Engineering, and Bureau of Chemistry and Soils. The breeding and improvement not only involves yield and quality but is also concerned with harvesting factors, the ease with which the cotton can be ginned and prepared for spinning, and the performance of the fiber when put to the final test in manufacturing processes.

A Survey of a Century and a Quarter of Work by Private Breeders

REFERENCE has already been made to the early sea-island breeders. They were undoubtedly pioneers in this field. While the fine cottons they produced have in a large measure disappeared, the methods they followed were in some instances at least passed on to breeders of a later day. Reference to some of the later sea-island breeders is included in the section which discusses the breeding work done by the United States Department of Agriculture.

Reference has also been made to the introduction of the Mexican stock by Walter Burling at Natchez, Miss., in 1806, and its subsequent introduction into South Carolina, about 1816. This variety seems to have continued through the years and was being bred as Mexican Big Boll by J. D. Hope of Sharon, S. C., in 1914, when R. Y. Winters secured seed as foundation stock for his breeding work in North Carolina.

Between 1830 and 1840 H. W. Vick of Vicksburg, Miss., possessed a variety designated as Belle Creole and described as having a long soft fiber, large productive stalks, and large long bolls. He selected from this a new variety, Jethro, which he sent to J. V. Jones of Henderson, Ga., in 1846, and which became the parent stock of Jones Long Staple, Six-Oaks, and other similar varieties. About 1840 Vick introduced another variety called Petit Gulf which became popular about 1846, and persisted in some localities until the appearance of the boll weevil. This variety was distributed in Georgia and Alabama and was probably the parent of several later varieties in these regions.

Boyd Prolific was one of the oldest upland varieties known to have been developed from a single plant. The original plant was found in a field of ordinary cotton by a Mr. Boyd. The variety, which was common in Mississippi about 1847, was described as semicluster with short fruiting branches, medium-size bolls, and short lint. In Georgia it became a parent of Dickson and other important varieties.

The variety known as Bohemian was developed about 1865 by a Bohemian settler named Supak, who lived near Austin, Tex. This cotton was known also by the name Supak and was apparently developed by some method of plant selection. It was a rather stable type and was prominent and popular in Texas for 40 or 50 years. The bolls were large and turned down on opening, thus protecting the lint in bad weather. The broad segments of the bur and the large involucral bracts also had a roofing effect over the closely clinging locks. In spite of the storm-resistant features the cotton was easily picked. The staple length was about fifteen-sixteenths of an inch. Bohemian is of historic importance now in that it is the progenitor of Rowden and of Express.

Among other famous varieties of the early days might be mentioned Parker, Bancroft Herlong, and Peterkin. Parker was originated in 1868 at Maxime, Miss., by John M. Parker, Sr., by selection from

some variety the name of which was not given. This variety was continued by careful selection and was rather widely grown for 30 to 40 years. It was one of the old bender types, famous for high quality in the early period of cotton culture in the Mississippi Valley.

Bancroft Herlong was originated about 1868. A Mr. Herlong in Alabama sent a dozen seeds to the editor of the Southern Cultivator, who gave them to Edward Bancroft of Athens, Ga. The variety was never very uniform, but it became the parent of several other important varieties through natural crossing and straight selection. It was widely grown for probably a quarter of a century.

The Peterkin variety, which was of the Rio Grande type, was originated about 1870 by J. A. Peterkin of Fort Motte, S. C., the seed having come to him from the "back part of Texas." This variety and its later derivatives have been considered preeminent for poor soil, for land with low moisture-holding capacity, and for generally hard conditions of culture.

AN EXAMPLE OF MODERN TECHNIQUE 75 YEARS AGO

It has been reported that John Griffin, of Greenville, Miss., produced the variety called Griffin from a cross of an old upland variety, known as Green Seed, and sea island. The objective was to produce green-seeded cotton with longer and finer fiber, and the variety was established in 1867. An opinion rather prevalent among growers, especially in the earlier period of cotton production, was that green seed was a mark of hardiness or yielding ability in cotton. The work is a remarkable example of cotton breeding because John Griffin at that early date employed what is essentially the back-cross method, approximately 50 years before the geneticists proved the method to be a scientifically sound one for present-day plant improvement.

With this work, which was begun about 1857, selection was practiced 5 years before hybridization was begun and was also continued on the parental lines while the steps in crossing were carried out. Extreme hybrid vigor was reported in the first generation; according to modern genetics this is pronounced in most crosses between species of cotton. The F_1 or first-generation hybrids were 12 to 16 feet high and very unfruitful. The F_1 was back-crossed on the green-seeded parental line by using the pollen of the latter. The offspring of each succeeding back-cross was pollinated by the constantly improved green-seeded parental line for 4 or 5 years. Because of the gradual disappearance of hybrid vigor and the use of the continuous back-crossing, the plants were reduced in size, and the fruitfulness was brought back to practically that of the green-seeded parent. Every successive cross from the green-seeded parental line made on the hybrid material was to stalks least resembling the sea island form but most nearly approximating the sea island lint. In order to keep the new variety pure, selection was practiced without intermission from the time of its establishment in 1867 to the end of the century.

The Griffin variety was one of the best of the upland long-staple cottons. However, it was not sufficiently early in fruiting and maturity to persist under boll-weevil conditions. Consequently this variety was no longer successful, and this was also the case with the other late-growing long-staple upland varieties so prominent in the Mississippi Valley prior to the advent of this destructive insect.

RECENT AND PRESENT-DAY WORK BY PRIVATE BREEDERS

Since the period of this early foundation work, which lasted to about 1870, private breeders have been very active and have developed a large number of varieties and strains. These are listed in historical order, with brief summaries, in the appendix (p. 732). Among the private productions that have made cotton history during this long period—many of which became parents of later strains or varieties—were Jackson Round Boll, Truitt, Cleveland, Jackson Limbless, Russell, Toole, Cook Improved, Boykin Stormproof, Mebane Triumph, Allen Long Staple, Sunflower, Half and Half, Rowden, Wannamaker-Cleveland, the Coker varieties and strains, the Delta & Pine Land strains, the Stoneville strains, certain Acala and Lone Star strains, etc.

A few private organizations have carried on breeding work over a long period of time on a large or relatively large scale and have produced several different lines of cotton.

A new variety of cotton was bred and introduced by A. D. Mebane of Lockhart, Tex., in 1900 and named Mebane Triumph by Seaman A. Knapp. Development and maintenance of this variety represents the longest continued work in the history of upland cotton in this country. A splendid combination of high productivity, stormproofness, big bolls, medium staple length, high quality of fiber, high lint percentage, and sufficient earliness to meet boll weevil conditions in the western area, the variety has served as foundation stock for newer strains and as parental material in some important hybrids. A. D. Mebane began his work in 1882 but did not market seed to any extent until about 1900.

During the first few years after 1882, Mebane studied existing types and varieties of cotton of his section of the country and concluded that although some of the smaller boll varieties ginned out a higher lint percentage, the big-boll storm-resistant type, such as Texas Stormproof, Bohemian, Myers, and a few others, represented more nearly the type required for that part of the Cotton Belt. Presumably he finally chose stocks of Texas Stormproof or Boykin Stormproof for his material. After the stocks were chosen in the early 1880's, they were never changed and are still maintained by his family on the original estate. However, Mebane did shift the ideal toward which he was working. About 1910 he began to select for longer staple, and in due time the length was increased to $1\frac{1}{16}$ to $1\frac{3}{16}$ inches. Along with this development was associated less stability, lower yield, and less gin outturn. At the time of his death in 1923, Mebane had begun to work back to a type with higher yields, better lint percentage, and a full inch staple. Since that date, Mrs. Mebane, Paul M. Mebane, and W. P. Patton, Jr., have continued the work.

When H. J. Webber, of the United States Department of Agriculture and some of his associates began cotton breeding and improvement work in 1898, D. R. Coker, of Hartsville, S. C., became interested in having a part of the program conducted on the farms of his father, J. L. Coker.

The Federal workers were interested in developing a long-staple cotton that could be grown in the main Cotton Belt and would supply the United States with the type of cotton at that time imported from Egypt in large quantities. Efforts to grow Egyptian varieties,

previously attempted from time to time, were renewed, and trials were made to hybridize Egyptian and sea island with upland varieties. Some of this work was done on the Coker plantations.

After it was found that the Egyptian varieties were unsuitable for the main Cotton Belt and that the hybridization of the species was of little promise, Webber and his associates and cooperators turned to the development of longer fiber through selection of upland varieties. The plants with the longest staple were propagated by the plant-to-row method. Those that bred true were further tested and multiplied. Among the varieties and strains thus developed were Hartsville, Columbia (fig. 3), Webber, Deltatype Webber, Lightning Express, Super Seven, Wilds, the Coker Cleveland strains, Farm Relief, Coker Clevewilt, and Coker Foster. These are summarized in the appendix (p. 736).

BEFORE *strains of cotton highly resistant to wilt fungus were developed, there were large areas in the Southeast that could not safely be planted to cotton. As a result of the breeder's work, it can now be grown without danger from the wilt hazard in every section of the South. Another result of breeding has been an improvement in the average staple length of the entire crop of approximately one thirty-second of an inch. Interpreted in terms of premiums and discounts prevailing in 1935, this meant an increased value for the 1935 crop of about 80 cents a bale, or a total of approximately $8,000,000.*

In 1934, 14,775 plant selections were made by the plant-breeding staff of the Coker's Pedigreed Seed Co. About 3,500 of the best of these were placed in plant-to-row tests in 1935. In addition, about 125 strains in first-, second-, and third-year increase blocks and fields were carried. Eight variety tests were conducted. About 50 acres are devoted to the variety and plant-to-row tests and a much larger area to the preliminary increasing of strains.

Plants selected for plant-to-row testing or strains for further development must measure up, in the judgment of the plant breeders,[1] to the length, uniformity, strength, and character desired in the contemplated variety. A seed-increase field of the variety, Farm Relief, is shown in figure 4.

As has been noted, H. J. Webber supplied the method or system of breeding and some of the original material and for many years

[1] The present plant-breeding staff of the Coker's Pedigreed Seed Co. are George J. Wilds, J. B. Norton, R. S. Cathcart, R. McDick, B. E. Smith, and E. H. Larrimore.

was a plant-breeding consultant for the company. In 1920 and 1921 he was employed as general manager and headed the plant-breeding staff.

S. Pressly Coker, a cousin of D. R. Coker, was a plant breeder for the company from July 1911 until 1920, when he organized the Humphrey-Coker Seed Co. at Hartsville. Since that date he has developed and distributed several scientifically bred varieties and strains of cotton, including Cleveland 20, Dixie 14, Carolina Foster, Delta 36, Cleveland 52, and Dixie Triumph 4.

Developments in Mississippi

The private cotton-breeding work in Mississippi has been closely allied with the Mississippi Agricultural Experiment Station from the standpoint of origin of breeding stocks utilized and the personnel employed. E. C. Ewing, cotton breeder for the Mississippi Station from 1911 to 1915, during the last year joined the Delta & Pine Land Co. of Mississippi, at Scott, to breed varieties more suitable for planting in the areas used by the company (fig. 5). J. W. Fox, who had been in charge of the Mississippi Station's branch station at Stoneville and later was director of the Mississippi Agricultural Experiment Station, had preceded Ewing in joining the Delta & Pine Land Co. to be general manager of farming operations. G. B. Walker, a later director of the Delta branch station at Stoneville, and H. B. Brown, who succeeded Ewing at the Mississippi Station as cotton breeder, both left the services of the Mississippi Station in 1922 and organized the Stoneville Pedigreed Seed Co. Ewing and Brown each obtained breeding lines from the Mississippi Agricultural Experiment Station.

On beginning the breeding program in 1915, L. K. Salsbury, president of the Delta & Pine Land Co., more or less prescribed the kind of cotton that Fox and Ewing should develop. It was to have the following characteristics: The earliness of Express; 1⅛-inch staple on hill or upland and 1$\frac{3}{16}$-inch on Delta land; bolls medium to large, five-lock, easily picked; gin outturn, at least one-third; lint strong, with high spinning value; plants wilt-resistant, somewhat semicluster, strong enough to support heavy fruiting, which must be early, persistent, continuous, not ceasing in midseason.

A combination of the good qualities of Express and Wannamaker-Cleveland, with the undesirable characteristics of both eliminated, appeared to be the objective sought.

While employed by the Mississippi Station, Ewing had made a number of crosses in the summer of 1914 between Express 15 and a selected strain of Wannamaker-Cleveland, as well as many crosses of these with other varieties and strains, and other crosses among these varieties and strains themselves. With the approval of the director of the station, a portion of the hybrid seed was taken to Scott when Ewing took up commercial breeding in 1915. The remaining stock was left with H. B. Brown. In subsequent years the progenies removed to Scott were studied by Ewing and the poorer combinations eliminated. Also from year to year new hybrids were produced and observed, and the less promising discarded. Some of these hybrids were intercrossed, and thus a rather complex set of hybrids was built up in certain cases. However, back-crossing in the strict sense was not followed. Individual plant selections from the superior hybrid stocks were made and the new strains developed by plant-to-

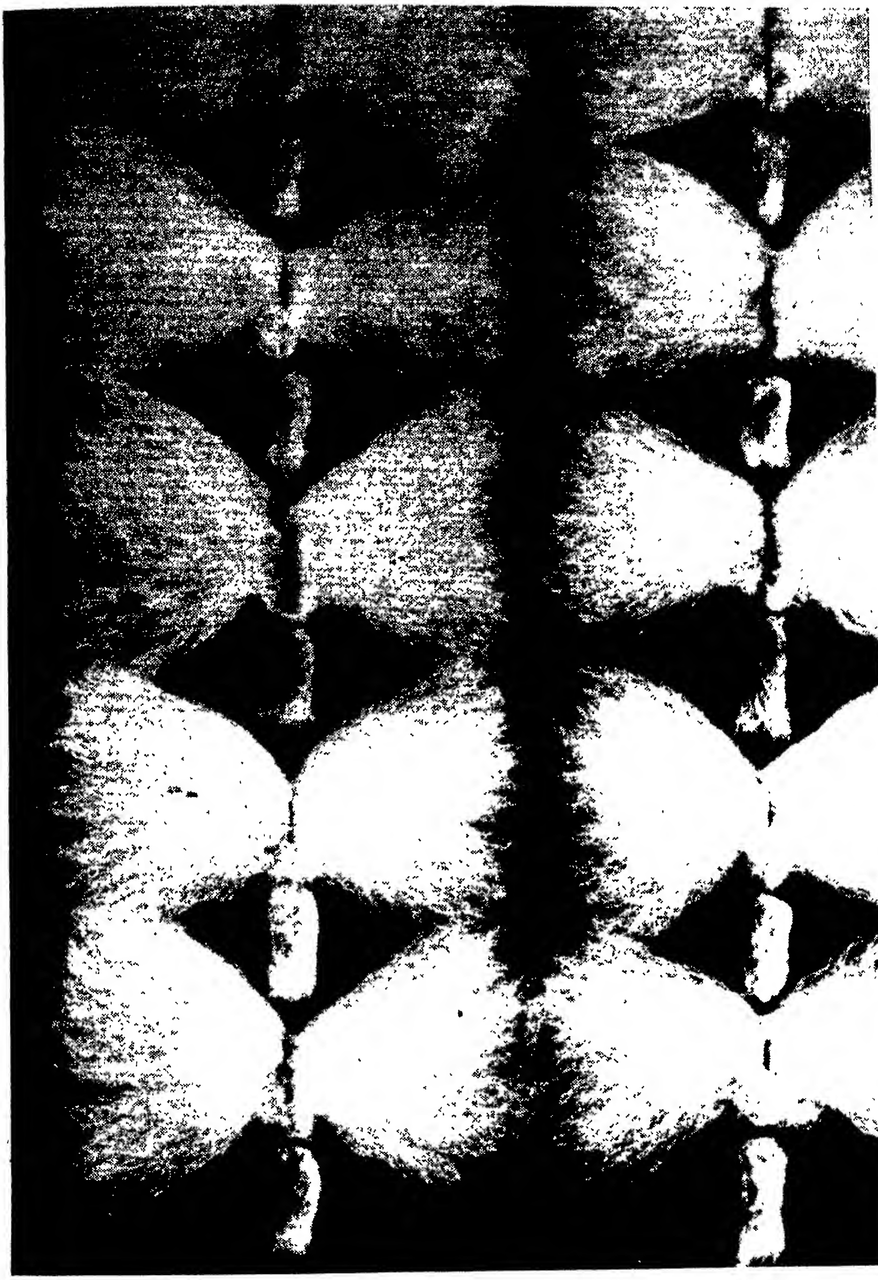

FIGURE 3.—Columbia cotton as selected from a good progeny row, 1910. Natural size.

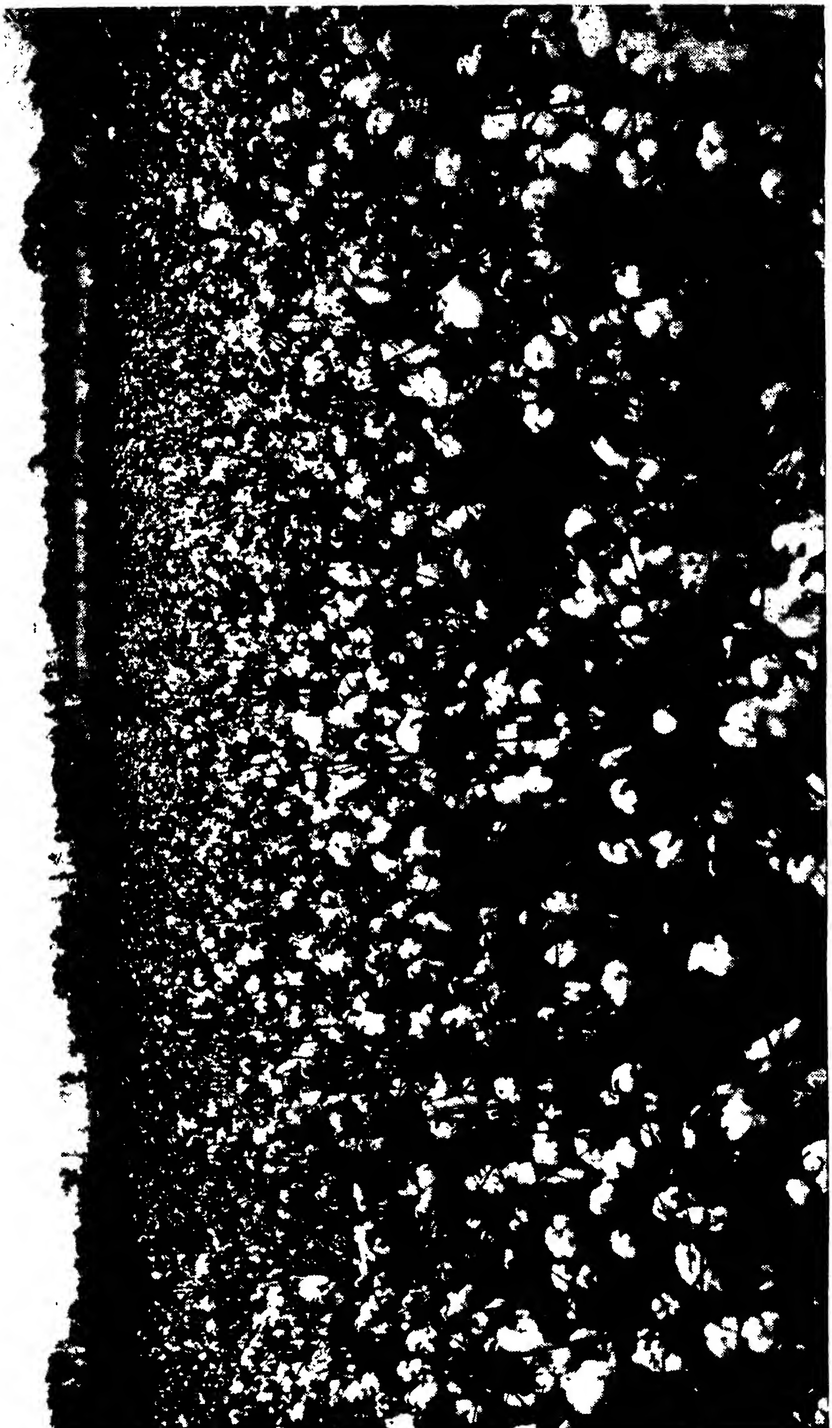

FIGURE 4.—A seed-increase field of a selected variety of cotton, Farm Relief, developed at Hartsville, S. C.

row testing and subsequent strain trials. The preliminary crossing and recrossing all were leading toward bringing out new strains and varieties.

The first product of this breeding and improvement program that seemed most nearly to meet the original specifications was the Salsbury strain or variety. All later strains or varieties also are of hybrid origin, coming from the 1914, 1915, and subsequent crosses. They include Delta & Pine Land 4, 6, 8, 10, 11, and 11 A (p. 738).

The Stoneville Pedigreed Seed Co. has bred, produced, and distributed Stoneville and certain strains of the Delfos 6102 type of cotton. H. B. Brown, assisted by C. A. Tate, conducted the breeding work from 1922 to 1926, when he joined the staff of the Louisiana Agricultural Experiment Station. Since 1926 C. A. Tate and G. B. Walker have carried on the breeding and improvement efforts them-

FIGURE 5.—Wagonloads of seed cotton at a private gin of a large cotton plantation, Scott, Miss.

selves. The seed stocks with which the company's breeding and improvement work was started were obtained, as noted above, from the Mississippi Station.

Stoneville, Rowden, and Other Famous Types

The Stoneville type of cotton is descended from Lone Star 65, selected in 1916 by H. B. Brown from an older Lone Star strain known as Lone Star 11.[2] Lone Star 65 was thought by Brown to be a natural cross with Mississippi Station Trice. Delfos 6102, now known as the Delfos type, is descended from a selection of Foster 120 made by Brown in 1916. Foster 120 in turn was a selection of Foster made in 1911. Lone Star 65 and Stoneville stocks have been continuously selected under open-pollination conditions since 1916, and Delfos stocks since 1911. The Stoneville type is a more or less general-purpose cotton adapted to a wide area. The Delfos type is suited to special areas like the bottom lands of the Mississippi Valley.

[2] Lone Star 11 was one of 3 strains selected by Ewing in 1911 from the original Lone Star, the others being no. 15 and no. 132.

The history of these two types is summarized under the names Stoneville and Delfos in the appendix.

Several commercial breeders and seed growers have operated in Arkansas, breeding and developing their own seed stocks, growing stocks bred by the Arkansas Agricultural Experiment Station, or utilizing both sources for pedigreed material.

About 1919 Robert L. Dortch began the production of pedigreed planting-seed stocks and the development of new strains out of these stocks. Dortch's first work was with the Meade and Express 350 varieties, but these stocks were later discarded and replaced by Arkansas Rowden 40. In 1923 the Arkansas Agricultural Experiment Station placed on the Dortch plantation 12 strains of Rowden which had been selected from Texas Rowden by J. O. Ware at the station farm near Scott. These strains, which were seed of first-year progeny rows, were planted in adjacent blocks. The 1923 season was a very unfavorable year in Arkansas from the standpoint of heavy weevil damage, leaf-worm injury, and shedding of fruit forms caused by rainy weather. Four of the 12 strains, designated as Rowden 1, Rowden 14, Rowden 25, and Rowden 40, stood out through these rigorous conditions as being distinctly superior, but all were subsequently discarded except the last. From 1927 to 1931 very successful crops of Rowden 40 were grown by Dortch, and the seed was widely distributed in Arkansas as well as in other States. The experiment station also grew and distributed the seed and designated the variety as Arkansas Rowden 40.

During the period from 1925 to 1931, additional Arkansas Station strains of Rowden were tried on the Dortch plantation, and Dortch continued his own breeding work with Rowden selections. Two superior strains have been bred and developed since 1926. In 1932 one of these, Roldo Rowden 40-2-9, replaced the parent stocks and is now widely grown in Arkansas and also to a considerable extent in some of the surrounding States. The other new strain is designated as Roldo Rowden 40-9-F-6-3-1 and probably will replace the former strain on the Dortch properties in 1937.

The recent strain, Rogers Improved Acala, produced and grown by John D. Rogers and J. H. McDonald at Navasota, Tex., is one of the best representative lines of the Acala 8 type. Rogers Improved Acala was first introduced commercially about 1923. Rogers began his breeding work in 1921, was assisted in 1922 by Henry Dunlavy, and has been assisted since then by J. H. McDonald. Several strains of the Acala 8 type have been introduced under the trade name of Rogers Improved Acala, but in 1931 a much improved strain replaced all previous stocks. This strain is more productive and has more round-nosed bolls and a gin outturn 4 or 5 percent higher than any of the previous Rogers lines. Rogers obtained his original breeding stocks, as noted elsewhere, from Department of Agriculture workers and from other private agencies who were growing pure seed of Acala.

In addition to those mentioned, a number of other private breeders and seed growers have operated in Texas, some of them over a comparatively long period of time. During the present century and particularly since 1920, these operators have produced and distributed cotton planting seed widely not only in Texas but in several of the surrounding States.

Among the new lines developed from such parentage as Lone Star, Mebane Triumph, Rowden, and Acala, are New Boykin, Ferguson

Triumph 406, Buckelew Mebane, Kasch, Bennett Lone Star, Lankart, Bryant Mebane, Sunshine, H-X, Russell, Worley Boykin, Young Improved Acala, Harper, Paris Big Boll, Qualla, Hurley Special, Cliett Superior, Hasselfield Lone Star, Texas Special, Chapman Ranch Mebane, Wacona, Aldridge A-1, Texas Mammoth, Bagley Better Cotton, and Watson. These are summarized in the appendix.

The Development of Acala 5 in Oklahoma

Several commercial cottonseed firms have grown and distributed planting seed in Oklahoma. One of these firms, operated by the late C. N. Nunn, was responsible for the development of the present Acala 5 type of cotton.

In the spring of 1914 D. A. Saunders of the United States Department of Agriculture sent a bushel of Acala seed to C. N. Nunn, then county agent at Okemah. Under Nunn's supervision, the seed was planted on an acre of land on the farm of L. A. Niells and isolated. In the fall of 1914 O. F. Cook, D. A. Saunders, and others of the Department visited this plot. With Nunn, they selected 96 plants which Nunn planted in progeny rows in the spring of 1915 on the Lynde & Darby farm near Porter. Nunn at that time had resigned as county agent and had become partner and manager in the Lynde & Darby farming operations.

Through the help of some of the Department cotton breeders, Nunn selected two of the best rows, no. 5 and no. 8, in the fall of 1915. D. A. Saunders preferred row 8 because of its similarity to the original Acala and returned all the seed production of this row to Clarksville, Tex. Nunn preferred row 5 as more suitable for conditions in Oklahoma because of its earliness. This was the beginning of the Acala 5 type. All other Department strains as well as the stocks of row 8 later became known as the Acala 8 type. Nunn put Acala 5 on the market as planting seed in 1918. It was distributed extensively in Oklahoma, Arkansas, and to some extent in the northern part of Texas until about 1927, when Nunn's new strain, Acala 5-37, replaced the parent strains in the Nunn's Pedigreed Seed & Stock Farm plantings. Shortly before his death in 1934, Nunn had developed and introduced a later strain called Nucala, shown in figure 6. Nunn made a distinct contribution to the cotton industry in developing, preserving, and distributing the Acala 5 type of cotton. His work provided breeding stocks of Acala for the Oklahoma, Arkansas, and Tennessee Agricultural Experiment Stations, and foundation stock for cottonseed companies in Oklahoma, Arkansas, and New Mexico.

Cotton Breeding in the Department of Agriculture From 1867 to 1936

THE effort made by the United States Department of Agriculture to provide improved or more suitable varieties of cotton for the Cotton Belt consisted mainly in the importation of foreign stocks until practically the beginning of the present century, when breeding

work with existing American varieties was begun by H. J. Webber, W. A. Orton, and their associates. During the latter half of the past century Department workers had worked especially with Egyptian cotton. Both Webber and Orton retested some of the Egyptian varieties, and the former attempted to adapt these varieties to the main Cotton Belt by applying more systematic methods of breeding than had been tried previously.

The much-increased interest of foreign spinners in Egyptian cotton, brought about by the cotton famine of the American Civil War, created a feeling that it might be necessary to grow this cotton here in order to recapture the trade that had temporarily shifted from the United States to Egypt. In 1867 the Department of Agriculture began the importation of cottonseed from Egypt and the distribution of small trial lots of this seed to many points in the South. Results of more than 50 experiments with the Egyptian cotton during the following 5-year period in various parts of the Cotton Belt were recorded, but most of these tests showed total failure and none was sufficiently successful to indicate that the cotton could be grown to advantage in the main Cotton Belt. After this series of failures about 20 years elapsed before Egyptian cotton was tried again by the Department of Agriculture.

About 1890, importations of Egyptian cotton at high prices by American mills stimulated a demand on the part of certain interests that the culture of Egyptian varieties be tried again. Between 1892 and 1894, seed of three of the varieties most prominent in Egypt at the time were imported and distributed in all the cotton States by C. R. Dodge. All plantings were discontinued and the stocks lost after the first trial except in one case at Floresville, Tex., where, because of the long season, W. H. Wentworth matured a good crop, continued plantings, and selected for acclimatization and adaptation for several years until he obtained a product apparently of high quality. However, after developing the seed stock, he had difficulty in making actual sales of the commodity and finally discontinued the undertaking.

In the latter part of the nineties L. H. Dewey imported more Egyptian cottonseed, had it distributed, and in one instance obtained a manufacturing test of the fiber. The test was made by the Ponemah Mills at Taftsville, Conn., with cotton of the Jannovitch variety grown by Robert Viewig of Godwinville, Ga. However, American mills still did not like American-grown Egyptian cotton and continued to get their supplies from abroad.

After H. J. Webber was put in charge of the plant-breeding work of the Department of Agriculture in 1897, he continued the trials of Egyptian cotton in the Cotton Belt and extended the tests to some of the river valleys of the Southwest, where irrigation could be practiced and where climatic conditions were similar to those of the Nile Valley. Webber selected plants for adaptation from year to year, using the Egyptian stocks that remained from Dewey's importation. He also worked with fresh stocks brought in from Egypt by David Fairchild, then in charge of foreign plant introductions. This new material was represented by the varieties Mit Afifi, Ashmouni, Jannovitch, Abbasi, and Gordon Pasha, and they were planted at many points all the way across the Cotton Belt from South Carolina to California. Plant-to-row breeding for adaptation was practiced, and experimental success was attained at several places, notably, Harts-

FIGURE 6.—A field of Nucala cotton, a recent strain of Acala developed at Porter, Okla.

ville, S. C.; Maxime, Miss.; San Antonio, Brownsville, and Del Rio, Tex; Carlsbad, N. Mex.; Yuma, Ariz.; and Calexico, Calif.

However, in the main Cotton Belt, where growers were accustomed to big-boll upland and where Egyptian in the long run is not suitable as a rain-grown crop, production did not extend beyond the experimental stage. Bacterial blight or black arm attacked Egyptian cotton seriously in the humid area and was one of the more important reasons why this type of cotton was not continued further in experiments in the East. The work was discontinued soon after 1900 except in the irrigated valleys of the Southwest, where prospects for developing a successful industry were better. T. H. Kearney, who was an associate of Webber's and was working on crops adapted to saline soils in the irrigated sections, became interested in the Egyptian-cotton adaptation studies in the Southwest and went to Egypt in 1902 to study the culture of cotton there. On his return he took over the breeding stocks maintained to that date by Webber [3] and continued the Egyptian-cotton breeding work begun by his predecessor. A more detailed discussion of this development will be given later in this article.

In the beginning of his cotton-improvement work, Webber studied the painstaking methods used by the sea-island growers to keep up the quality of their crops, and utilized them with some adaptation.[4] He carried on the isolation of long-staple strains of upland cotton mainly in South Carolina, at Columbia and at Hartsville. His assistants and associates worked at various points in the main Cotton Belt to develop upland varieties either with better staple or with better adaptation to boll weevil conditions, the latter work being confined at this time to the western end of the main Cotton Belt, especially in northwestern Louisiana and Texas.

The history of the long-staple upland varieties that were developed at Hartsville, S. C., has previously been referred to in connection with the discussion of the breeding work of the Coker's Pedigreed Seed Co. Webber developed the Columbia variety and D. N. Shoemaker assisted in breeding the Hartsville variety. In Webber's 1902 trials, several plants of the Russell variety were found to have extra long staple—these perhaps being natural hybrids—and Columbia was developed from the one plant with the longest staple (1⅜ inches).

In his experiments on the plantation of R. C. Keenan at Columbia in 1903, Webber found a few plants of Jones Improved with lint from 1⅛ to 1¼ inches in length. From these he developed Keenan after five generations of selection and testing. The lint of the new variety was slightly coarser and shorter than that of Columbia, and uniformity of fiber length was less well established, but Keenan became known as a useful variety. It was fairly early and productive and had bolls that opened well.

The work of D. N. Shoemaker in assisting in the development of the Hartsville long-staple variety was done in 1903 while he was

[3] In 1900 Webber grew about 3 acres of Mit Afifi in the Imperial Valley, Calif., on land where Calexico now stands. This was the first year water was turned into the irrigation canal and the cotton was the first grown in the valley. A number of selections were made from this patch, which marked the real beginning of the American-Egyptian industry in this country.

[4] A summary of the cotton-breeding personnel in the immediately succeeding period is of some historical interest. 1897-1907, H. J. Webber carried on cotton breeding in the Department; in 1899 W. A. Orton, in another division of the Bureau of Plant Industry, began work on cotton wilt, cooperating closely with Webber; in 1900 T. H. Kearney began work with Webber, and started work with Egyptian cotton in the Southwest in 1903; in 1904 D. N. Shoemaker began work with Webber and in 1908 he succeeded Webber in cotton breeding and continued until 1910; in 1911 O. F. Cook took over the cotton investigations of Webber and Shoemaker.

located in Hartsville, S. C., as a teacher of botany in a local school and cotton breeder for D. R. Coker. W. C. Coker, a botanist at the University of North Carolina, Chapel Hill—brother of D. R. Coker—had made 30 plant selections out of a field of Jones Improved grown on the Coker farm at Hartsville the year before, 1902. Plant selection in these early days is illustrated in figure 7. In 1903 the selections were planted on the Coker Plantation and supervised by Shoemaker. In 1904 this breeding work was taken over by D. R. Coker, who continued to select the breeding lines until one of them was isolated as the most outstanding. This strain was called Hartsville. It was closely related to Keenan and was also related to Columbia. The staple of Hartsville measured 1⅛ to 1$\frac{3}{16}$ inches and was very uniform, both in length and strength. However, after the boll weevil arrived in South Carolina, Hartsville was replaced, along with Keenan and Columbia, by earlier varieties.

FIGURE 7.—Photograph taken more than 30 years ago, showing two individual plant selections made out of the Jones Improved variety at Hartsville, S. C., during the early cotton breeding work of H. J. Webber and his associates.

BREEDING EXPRESS AND LONE STAR, AND WORK WITH OTHER FOUNDATION STOCKS

Express was developed by Shoemaker shortly after his appointment with the Department of Agriculture in 1904, when he was sent to Texas to work on the development of earlier varieties of cotton to meet boll weevil conditions and also to improve staple quality and length. In the fall of 1904 he found a single prolific early plant with good staple in a field of mixed cotton, thought to be chiefly the Bohemian variety, near Paris, Tex. Called Express because of its speed in fruiting and maturing, the strain developed from this plant reproduced the character for rather extreme earliness in a remarkably uniform manner and the longer staple quality to a marked degree. However, the bolls were small and not storm-resistant, so that the

type did not appeal to Texas farmers, who were interested in big bolls and storm resistance. Seed stock was carried along and grown to some extent for further observation until 1910, when E. C. Ewing obtained some of the seed and developed the variety in the Mississippi Delta.

A. W. Edson began cotton-breeding work in Texas in 1901. His efforts, like those of other Department workers, consisted chiefly in developing earlier strains with better staple than the existing or parental varieties possessed. Several strains of King were produced with fiber ranging in length from 1⅛ to 1¼ inches. However, like Express, these were not well received by Texas farmers and were not cultivated to any extent. The development of several early strains of the Big Boll and Stormproof group of Texas varieties was started by Edson before his death in 1905.

The efforts of F. J. Tyler while employed in the Department of Agriculture did not concern cotton breeding and improvement work directly but were devoted to a comprehensive effort at the identification of the upland varieties and their relative economic importance and classification. In this work 613 varieties and synonyms were described or listed.

The work of D. A. Saunders was concerned with cotton breeding and improvement in the main Cotton Belt States west of the Mississippi River, chiefly in northwestern Louisiana and in Texas. He developed the Lone Star, Foster, and Holdon varieties, and assisted in the breeding of others. He also supervised the multiplication and distribution of pure cottonseed stocks and was the first superintendent of the United States Cotton Breeding Station at Greenville, Tex., in 1918.

The development of Lone Star, named for the Lone Star State, began in 1905, when D. A. Saunders selected some plants individually from a field of cotton—understood to be a variety known as Jackson—located in the Colorado River bottoms near Smithfield, Tex. The variety was doubtless from stocks of Jackson Round Boll. One strain, isolated by plant-to-row testing in 1906 and 1907, had a short-jointed main stem, rather early fruiting tendencies for the Texas Big Boll group, large and blunt-pointed bolls, lint 1 to 1⅛ inches, very strong and uniform in length, and a gin outturn of 38 to 40 percent. This strain was tested at several points in Texas, multiplied, and introduced to farmers in 1909 as Lone Star. It has been very prominent in Texas, and to some extent in parts of surrounding States, since that date, and has served as foundation stock for a number of other Lone Star strains and hybrids, notably Stoneville.

In his early work, Saunders also made crosses between Texas Big Boll varieties and eastern varieties which were earlier or had longer staple. One of his crosses, made in 1904 near Shreveport, La., between Mebane Triumph and Sunflower, has become famous as the beginning of one of the most important groups of cotton of the present time.

The object in making this cross was to develop a medium long-staple variety with as large bolls as possible and also sufficiently early to produce profitable yields under boll-weevil conditions. Plants were selected from the hybridized material and grown in separate rows on the farm of J. F. Foster, of Shreveport, La. Several years were required to establish the kind of strain sought and to purify it of aberrant forms. Throughout the development period the selec-

tion was carried out under conditions of heavy weevil infestation, so that the type of plant that could best survive stood out markedly. Though as yet not entirely pure, the variety was introduced to some extent in 1909 and given the name of Foster, after which it was subjected to further selection. Foster never became very important in Texas, but it spread eastward and soon became prominent and extensively grown in the large river valleys. In 1911, E. C. Ewing introduced it into Mississippi and used it as part of his foundation stock for further breeding.

TWO FAMOUS COTTONS—DURANGO AND TRICE

At the St. Louis Exposition in 1904, F. L. Lewton observed some excellent cotton plants and bolls in an exhibit placed there by the Mexican Government. This material was supposed to have come from the State of Durango, Mexico. Lewton obtained a small

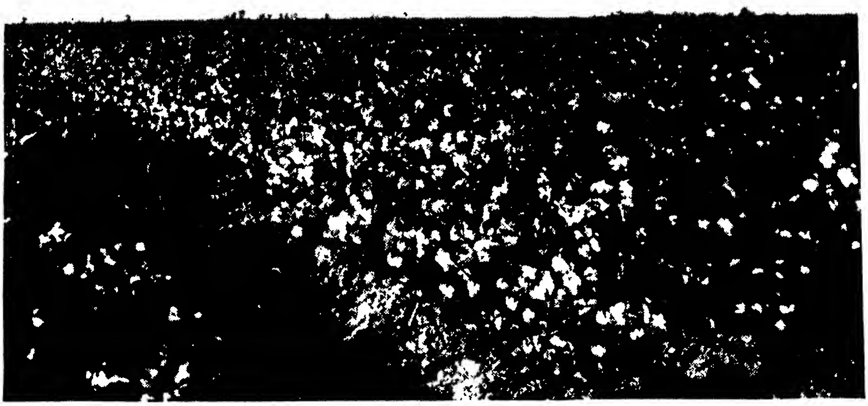

FIGURE 8.—Field of cotton showing progeny rows at El Centro, Calif. Durango (upland) variety, 1912

quantity of seed from the Mexican representative in charge of the exhibit, and in 1905 a few of them were planted at several points in south Texas, chiefly at Del Rio and San Antonio. In 1907, at Del Rio, a superior strain was recognized and during the next few years isolated and multiplied. In 1911 trials of the new acclimatized strain, which had become known at that time as Durango, were made in various places in the Cotton Belt. It was thought, however, to be more suitable for south Texas and the Southwest, and consequently was tried out in the district around Del Rio and in the Imperial Valley of California (fig. 8) more than in other parts of the country.

In the Imperial Valley in 1911, three acres of Durango were grown on the farm of W. E. Wilsie near El Centro. About 200 acres were planted around El Centro and Holtville in 1912. By 1913 the Durango variety had become very popular in the Imperial Valley, and California farmers not only planted all the seed from the 200 acres grown in 1912 but obtained all the pure seed stocks that were available in Texas. As developed in the Imperial Valley, it became the

first upland variety to be grown on the one-variety community basis. It also did well in many of the upland long-staple areas of the humid part of the Cotton Belt and was grown to a considerable extent in some of the large river valleys until it was replaced by Express and Delfos. In the irrigated districts of Texas and the Southwest it was the most popular upland cotton until it was replaced by Acala.

From 1904 to 1919 S. M. Bain, of the Tennessee Agricultural Experiment Station, Knoxville, served as a collaborator in the Bureau of Plant Industry, working on the breeding and development of early and more productive varieties of cotton with better staple length, and making laboratory and other experimental tests with the breeding material used. Oil analysis was made to determine whether or not the oil content could be increased by breeding. Ovules and pollen were chemically treated to determine the effects, if any, on the progeny. Albert T. Anders, an employee of the Department from 1907 to 1915, for a time assisted Bain in this work.

As far as breeding and improvement work is concerned, Bain and Anders are chiefly remembered for the development of the Trice variety from plants selected by Bain in 1904 in a field of early cotton on the farm of Luke Trice near Henderson in Chester County, Tenn. After several years of selection and testing, by 1908 much improvement over the original variety was exhibited in all the qualities sought as well as in uniformity. The plant was small, very early, very prolific, boll medium size, lint percentage 28 to 33, staple fine and seven-eighths to fifteen-sixteenths of an inch in length. Trice was earlier than King and was superior to this variety in size of boll and length of fiber.

Trice was very popular for almost a quarter of a century along the northern rim of the Cotton Belt. Its tendency not to develop excessive vegetation on soils with abundant nitrogen and moisture made it popular for newly cleared land and low bottom lands. During the worst part of the boll weevil era, Trice spread farther south, especially in the central part of the Cotton Belt. In this period E. C. Ewing and H. B. Brown of the Mississippi Agricultural Experiment Station developed a strain of Trice called Mississippi Station Trice. J. O. Ware of Arkansas and Glen Briggs and L. L. Ligon of Oklahoma also developed strains of the variety. The stock of Trice was maintained by Bain and Anders in Tennessee during their service with the Department of Agriculture, through cooperation with seed-grower farmers. W. W. Ballard and D. M. Simpson of the Department have maintained strains of Trice since 1919.[5]

THE FIGHT AGAINST THE WILT FUNGUS

In 1895 the cotton wilt disease had spread to an alarming extent over the territory where sea island cotton was being grown. The growers called on the United States Department of Agriculture for assistance. Erwin F. Smith responded, going to James Island, S. C. (fig. 9), and spending 4 weeks on W. G. Hinson's farm investigating the nature and cause of the disease. During the same year E. L. Rivers, a neighbor of Hinson's, resorted to the old sea island system of selection as a

[5] A few commercial breeders in the territory where Trice has been popular have assisted in the preservation of the variety, have developed more recent strains, and have distributed the seeds widely. A. F. & J. F. Bridger of Bells, Tenn., and the Burdette Plantation, Burdette, Ark., are notable in this respect. J. F. Bridger discontinued his work only a few years ago, but the Burdette Plantation still produces some Trice seed. Some of the strains developed by this firm and by the Arkansas Agricultural Experiment Station have produced a staple length of 1 to 1$\frac{1}{16}$ inches and a lint percentage of 33 to 34.

means of developing a wilt-resistant variety. The seed of the first plant selected in 1895 was multiplied on badly infested land in 1896 and in 1897. At the end of the 2-year period the new strain possessed a satisfactory degree of wilt resistance, but the fiber did not come up to the standard for the sea island commodity, either in uniformity of length or in general quality. The strain was abandoned and efforts to find a desirable single plant in Rivers' fields were resumed. In 1899 such a promising specimen was obtained.

Cotton wilt had also occurred in many sections of the upland cotton areas of the Southeast. The presence of this problem both in sea island and upland territory had caused Congress to make an appropriation for the Department of Agriculture to study and devise control measures. The Department promptly gave attention to the problem. In 1898, H. J. Webber visited James Island, consulted with Hinson

FIGURE 9.—Field of sea island cotton as grown on the islands off the coast of South Carolina before the passing of this industry in the United States.

and Rivers, and inspected the latter's selection work, and in 1899 W. A. Orton went to the island and urged Rivers to continue his work.

Many experiments such as seed treatments and soil treatments with varying quantities of lime or fertilizer were devised by Orton and tried out for wilt control by cooperating farmers on James and Edisto Islands in 1900. None had any effect on the disease.

In connection with these experiments on his farm in 1900, Rivers planted the seed of his 1899 selection as controls on some badly infected land that was untreated. The progeny from this selected plant was fully resistant and the lint produced proved to be commercially satisfactory. In 1900, Webber and Orton urged him to multiply the strain. One acre was planted in 1901 and 15 acres in 1902. At the end of the latter year, Orton, through the United States Department of Agriculture, purchased a large part of the seed from Rivers and distributed quantities to other sea island growers. This strain was known as the Rivers variety.

Orton and Rivers together selected a second variety which was resistant to wilt and coarser in quality of fiber than the Rivers variety.

The object was to combine with wilt resistance greater productiveness and general hardiness rather than especially long staple. The variety was designed more particularly for the mainland of Georgia and Florida, where the finest quality and longest staples were not so important as good yields, hardiness, and disease resistance. In 1900 Orton selected the first plants out of a field of sea island infested with wilt on Edisto Island, and in 1901 grew a plot planted from these selections on the same farm. In 1902 the stock was transferred to James Island and planted in a wilt-infested field on E. L. Rivers' place. After further selection, in 1903 one row proved to be outstanding for wilt resistance, general productive characteristics, and uniformity of staple, but the fiber was somewhat shorter and coarser than the island type. This row was propagated and became the Centerville variety, named after the Rivers place, which was called Centerville Plantation. The Centerville variety became an important wilt-resistant one for the sea island cotton farms of the mainland.

At the time Webber and Orton became interested in the wilt problem in sea island cotton, Orton also began work in wilt-infested areas of upland territory, especially one in the upper Coastal Plain of South Carolina around Dillon and Lamar, and another in southeastern Alabama around Troy and Headland. The wilt disease was more prevalent in these two general areas at that time but was also known to occur to a less marked extent in eastern and southern Georgia and had been reported in Florida and in Arkansas.

At first Orton followed the same general plan tried with sea island—seed treatments, fertilizer and lime tests, and variety comparisons. Study soon indicated that the only practical solution for control of the disease was the breeding of wilt-resistant varieties. Orton's early experience indicated that mass selection did not suffice but that individual plants must be obtained from inherently resistant stocks and grown by the progeny row method on wilt-infested land. This was necessary not only to obtain a high degree of resistance but to maintain the necessary uniformity in plant growth factors and in staple quality.

Development of Wilt-Resistant Upland Varieties

In 1900 an experiment was started by Orton on the farm of H. L. Galloway of Dillon, S. C. The field was heavily infested with the disease. In this experiment, plots of local varieties as well as varieties brought in from other localities were tried. Among the varieties introduced were three Egyptian and one sea island. The highest degree of resistance was found in the three Egyptian varieties. Jackson Limbless, an upland variety, ranked fourth. Sea island ranked fifth, and showed considerably more damage. There were 13 other upland varieties included which were all much less resistant than Jackson Limbless or the others; several were very susceptible to the disease. Selection and retesting of the more resistant plants of the Jackson Limbless stock were continued until 1905, when it was introduced as a new variety under the name of Dillon, after the place where the work was done.

Dillon was the first upland wilt-resistant variety developed by systematic methods. It was extremely resistant to wilt and somewhat resistant to root knot, but had little else to recommend it. It was an extreme cluster type, shed badly during dry spells, was

hard to pick and produced staple of about seven-eighths of an inch. After Dillon was introduced, however, it was widely grown and was used as a parent in a number of hybrids with other upland varieties to introduce wilt resistance.

The second wilt-resistant variety was developed at Troy, Ala., by the plant-to-row method from selections originally made in 1902 on wilt-infested land. One strain from Peterkin, presumably a hybrid with some other variety, eventually proved to be uniform and highly resistant to wilt. The type of plant finally developed had the pyramidal habit of branching like Peterkin, and this made it better liked than Dillon. The new variety was called Dixie and was a considerable improvement in earliness, size of boll, and lint percentage over the old Peterkin.

W. W. Gilbert began work with the Department of Agriculture in 1904 as assistant to W. A. Orton on the cotton-wilt problem. L. O. Watson, as an agent working with H. W. Barre at the South Carolina Agricultural Experiment Station from 1911 to 1914, assisted with the breeding for resistance. In 1914 Watson took up full-time work with the Department and kept on with the project in the Southeast until it was discontinued in 1920. C. A. McLendon replaced Watson at the South Carolina Station in 1914 and for 2 years assisted Watson in the cotton wilt work after Gilbert left it.

The development of Dixie suggested the importance of hybridization as a method of obtaining wilt-resistant varieties. The need for varieties with as much rapidity in fruiting and general earliness as possible, in addition to wilt resistance, was suggested by the advance of the boll weevil from the west. It was desired that a variety with larger bolls, longer lint, and a higher lint percentage than either Dillon or Dixie be developed. In 1908, 1909, and 1911 a large number of hybrids were made between Dillon and Dixie and between these varieties and several of the larger-bolled, early varieties that had been successfully grown in boll weevil areas or had characteristics that apparently would be suitable under such conditions. These varieties were Triumph, Cook, Pride of Georgia, Columbia, Webber, Foster, and Trook (a hybrid between Trice and Cook).

The leading variety developed out of this work was Dixie-Triumph. This is still an important wilt-resistant variety and is being bred at present by commercial breeders in South Carolina and by the Louisiana and Arkansas Agricultural Experiment Stations. Dixie-Cook was another new variety developed out of this work, but it did not enjoy the popularity of Dixie-Triumph.

Another important wilt-resistant variety developed by selection in Alabama was Cook 307–6. This variety was introduced in 1913 and subsequently disseminated widely in the wilt-infested sections of Alabama. The development of the variety was accomplished through the cooperative effort of Gilbert, Watson, and the Alabama Station. H. B. Tisdale, employed jointly by the office of Cotton and Truck Crop Diseases and the Alabama Station from 1914 to 1920, worked on the breeding and the distribution in Alabama of the wilt-resistant varieties Dixie, Dixie-Cook, and Dixie-Triumph. However, it was found that none of these responded to conditions in that State as readily as the Cook 307–6.

The success of the wilt-resistance work of the Department with upland cottons had stimulated State cooperation in South Carolina, Georgia, and Alabama, and also interested farmers and seed firms in seed production and in breeding on their own account. During the latter portion of their services with the Department and coop-

FIGURE 10.—On the slopes of the mountains of eastern Guatemala the native Kekchi Indians planted small patches of cotton, and, under the protection of the kelep ants, good yields of fiber were regularly obtained for homespuns, 1905.

erating institutions, Watson, McLendon, and Tisdale devoted most of their efforts to supervising the production and distribution of wilt-resistant varieties grown or bred by private cooperative growers and breeders.

While on a trip to portions of Central America in 1902 O. F. Cook, who was then in charge of investigations of tropical agriculture in the Department, observed among the Kekchi Indians (fig. 10) of eastern Guatemala, a dwarfy upland kind of cotton which was apparently much less injured by the boll weevil than was a nearby tree of a perennial cotton. This interesting fact was reported back to the Department, and 2 years later an expedition was sent to study the nature of varieties of cotton grown by the Guatemala Indians under weevil conditions. The season in 1904 had been much more rainy than in 1902, and the small, dwarfish, annual variety cultivated by the Kekchi Indians exhibited plants of larger size and much more promising appearance. A few weevils were found on this cotton, but they apparently were being held in check by some agency. Investigation showed that in fact several agencies proprotected the plants from severe weevil damage. One was an insect, the so-called kelep or Guatemalan cotton boll weevil ant, which was predatory on the boll weevil and was attracted to this type of cotton by the large production of nectar from two sets of extra floral nectaries on the involucral bracts.

FIGURE 11.—A single plant of the native Kekchi cotton in Guatemala showing large crop of bolls, 1905.

Several features of the plant itself worked together in an extraordinary manner to give it protection. In addition to the excessive and extended flow of nectar which attracted the kelep, this cotton had the habit of rapid growing and early fruiting. Protective morphological structures other than the nectar glands were the effective proliferation or abnormal growth of tissues in young buds and bolls attacked by the weevils; the small involucral bracts; and excessive hairiness over the plant surface. The rapid growth of the tissues around the punctures where the weevil eggs were laid and around the larvae served to close in on the young insects and kill them. In other districts of Guatemala native cottons were obtained with the small involucral bracts that enabled turkeys to find the weevils and devour them. A single plant of the native Kekchi cotton is shown in figure 11.

Seed of some of the most promising Kekchi cottons were sent to H. J. Webber and were planted in 1905 not only in south Texas but

at some other points in the United States. When planted at Pierce, Victoria, and several other points in Texas the Kekchi cotton was rank in growth and showed great diversity in plant and fruit characters. Several of the more luxuriant plants remained completely sterile; others produced a few bolls near the end of the season. On the other hand, in northern localities in Kansas and Maryland the plants were small, there was not as much diversity in type, and some of them matured fruit. Some of the plants which produced a few mature seeds were continuously propagated and the better individuals were selected until a definitely adapted productive type was obtained. However, no strains sufficiently superior to existing

FIGURE 12.—An experimental field of cotton in Eastern Guatemala, where several varieties of cotton popular in the Unted States were grown by Department specialists for comparison with the native Kekchi cotton, and for further studies of the kelep or boll weevil ant, 1905.

American varieties or to certain other introduced and acclimatized sorts ever came out of Kekchi to justify a general introduction, though it has been a local favorite in several districts. A few adapted strains of Kekchi have been continued by the Department until the present time in order to preserve the type and have it available for breeding material if some of its special characteristics should prove valuable for meeting particular requirements.

Several other types previously observed in the weevil-infested districts of eastern Guatemala were brought into south Texas and into southern California during a few years after 1905. Other parts of Central America and southern Mexico also were explored during this period for cottons which were persisting in the presence of boll weevils. An experimental planting of United States varieties was made in eastern Guatemala (fig. 12).

Introduction of Acala from Mexico

The seeds of two types of upland cotton, which later became known as Acala and Tuxtla, respectively, were obtained by G. N. Collins and C. B. Doyle when on a trip in southern Mexico (fig. 13) in the winter of 1906 and 1907 investigating cotton culture under boll weevil conditions in that region. The seeds of these were included in the acclimatization experiments at Victoria, Kerrville, and Del Rio in 1907, along with other foreign stocks being studied in south Texas during that period. The two stocks were each selected for adaptation through a period of years. However, the Tuxtla sort was never multiplied and distributed to farmers.[6]

Little difficulty was encountered in acclimatizing the Acala, and most of the plants were fertile and productive during their first season in Texas. At the San Antonio field station Acala was grown under conditions that demonstrated resistance to drought, ability to produce crops in a short period, and persistence among boll weevils.

FIGURE 13.—General view of small patch of cotton with owner, taken at Acala, Mexico, by G. N. Collins and C. B. Doyle, December 1906.

In 1909 an outstanding type was isolated, and in 1911 it was grown in a field near Waco, Tex. The work at Waco was in charge of D. A. Saunders. During the years 1912 and 1913 Saunders isolated three strains, designated as No. 1, No. 2, and No. 3, and also increased the bulk stock. No. 1 and No. 2 were kept in Texas, while the increase from No. 3 was the bushel lot of seed furnished C. N. Nunn at Okemah, Okla., in 1914, already mentioned.[7]

[6] When adapted and grown in this country, it appeared uniform, had a desirable staple, and still possessed the very large bolls, but the type required a growing season too long for boll-weevil conditions. Several years later it was noted that Tuxtla had possibilities in the irrigated areas of the Southwest, where boll weevils do not occur, but it never replaced the more popular Durango and Acala varieties grown there at that time. Stocks of the variety have been maintained by the Department chiefly because of the interest in preserving a seed source of a jumbo type of bolls.

[7] The stocks from the bulk lot of the 1911 Waco planting, the No. 1 and No. 2 selected stock from this Waco planting, and the No. 8 returned from Oklahoma, have all been considered in later years as belonging to the Acala 8 type in contrast with the Acala 5 type developed and propagated by Nunn. The existing stocks classified under the No. 8 type may not all be traceable to a certain definite breeding line handled by Saunders. However, the stocks used by John D. Rogers, Navasota, Tex., the Sugarland Industries, and the Sartartia plantation of Sugarland, Tex., since 1930 were developed from the No. 1 strain established by Saunders in 1912 and 1913. The last two agencies are affiliated with Rogers to the extent that the latter provides their seed stocks. Previous to 1930 the breeding lines of Acala used by Rogers and the affiliated firms had been isolated from among a collection of all Acala stocks that were available in 1922 when the breeding work was started at Allenfarm, Tex., by Henry Dunlavy, who became cotton breeder for the Rogers Co. at that time. Stocks were collected from C. N. Nunn as well as from the U. S. cotton-breeding station at Greenville, the D. A. Saunders Seed Co. of Greenville, and other sources.

During the development of Acala from about 1911 onward, a considerable acreage was grown by farmers around Clarksville and Greenville, Tex. Some of these stocks at a rather early period in their development were carried to the Southwest and tested in the irrigated valleys. The first field planting of Acala cotton in California was in 1919, at Bakersfield in the San Joaquin Valley, from seeds brought from Clarksville, Tex. A record shows that two progenies out of the Acala 8 type and three progenies out of some of the other Acala stocks grown at Clarksville were transferred to California in 1921 and continued there, where they could be better cared for because of the isolation and the breeding methods used in community production. Figures 14 and 15 show Acala cotton in California.

From the 8-acre field planting at Bakersfield in 1919, 350 acres were planted in neighboring districts in 1920. Also a small planting of this same seed was made in 1920 at the United States Experimental Date Garden near Indio, Calif. The planting at Indio stimulated the farmers of the Coachella Valley to organize for the one-variety-community production of Acala in the fall of 1920.[8]

Meade—A Superior Cotton Ruined by Mixing Seed

In 1912 Roland M. Meade selected a few exceptionally desirable plants in a field near Clarksville, Tex. The plants possessed lint over 1½ inches long and had black seeds, practically devoid of fuzz.

FIGURE 14.—Field of Acala cotton grown at Indio, Calif., 1921.

The fiber more nearly resembled that of sea island than had any other long-staple upland cotton before developed. The parent stock from which Meade selected his plants could not be definitely traced. At the time, the local information was that the cotton had been brought to Clarksville from Arkansas several years before. It was somewhat

[8] Such strains of Acala as California Acala, Shafter Acala, College Acala, Queen Creek Acala, Lyon Brothers Acala, Cody Lenz Acala, and Acala S-5 were developed from the stock grown in the date garden at Indio in 1920. A strain of Acala 8 in Tennessee has been developed by that station from seed of the strain designated as California. The "Slick" Seed Acala, or strain 1-13-3, came from the Shafter strain of Acala and was selected at the U. S. Field Station, Shafter, Calif. Tidewater, which was developed in the sea-island area of the Southeast, came from the strain designated Acala S-5, which was carried to James Island, S. C., about 1926 or 1927. The California and Acala S-5 strains were developed in California, the Queen Creek in Arizona, the College Acala in New Mexico, the Lyon Bros. strain at Geary, Okla., and the Cody Lenz strain at Austwell, Tex. Okra Leaf Acala and Stewart Acala were developed from some of the stocks that were transferred from Clarksville, Tex., during the early part of the distribution period of the variety.

indiscriminately referred to as Black Rattler or Blackseed, but the description did not correspond very closely to descriptions of either of these varieties as found in other sections of the Cotton Belt.[9]

Meade was the first to appreciate the possibilities of breeding a superior stock from such material, and the work was well under way at the time of his death in 1916. Three generations of progenies had been developed from selected individuals and a superior stock isolated. This superior line was named in Meade's honor. After his death, other workers in the Department of Agriculture continued the breeding work with this material. Some of the new variety was transferred to James Island, S. C., in 1916, since it had occurred to those working with Meade that this variety might serve as a substitute for sea island, after it was found that the latter could not survive the boll weevil.

FIGURE 15.—Acala cotton plant selected at Indio, Calif., 1921.

On being tried in the Southeastern States, Meade produced a staple length averaging 1⅝ inches and showed exceptional uniformity with little tendency to shortened lint at the base of the seed, the so-called "butterfly" shape. When tried under boll weevil conditions in southeastern Georgia, the yield was three or four times that of sea island. On the markets Meade lint was received in competition with sea island. Several bales were sold in 1917 on the Savannah market at a premium of a half cent a pound above the current price of mainland sea island.

Apparently Meade was on the way to becoming a striking success. More than 10,000 acres were grown between 1920 and 1922, but mixing of seed and planting in close proximity to fuzzy-seeded upland varieties resulted in a rapid contamination in the stocks, the mixed fiber was rejected by the trade, and the variety was largely abandoned after 1925. In 1933 some breeding work was resumed on James Island with Meade, and more recently this has been continued in cooperation with the South Carolina Agricultural Experiment Station.

At the James Island Acclimatization Station and through cooperation with growers, the Department maintained and selected several sea island varieties and strains (fig. 16). These consisted of two new

[9] Tyler lists both Black Rattler and Blackseed. The former was a "quarter" cotton grown rather extensively in the Mississippi Valley previous to the boll weevil period, and the latter was a name applied generally to sea island cotton but in some sections to a smooth-seeded Peterkin, which was a short cotton.

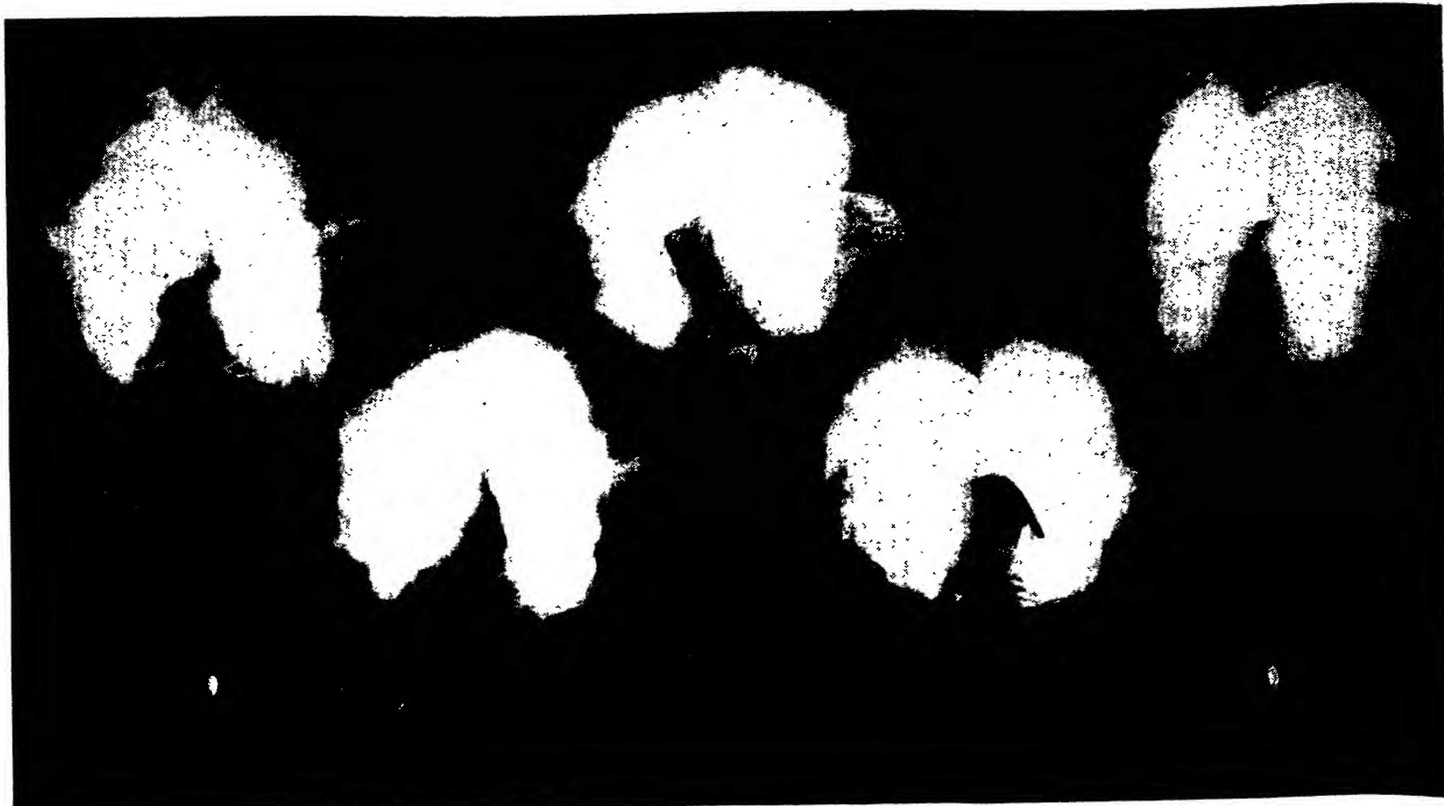

FIGURE 16.—Typical bolls of sea island cotton. Natural size.

strains developed from the old Seabrook variety, two strains of the Bleak Hall variety, and two earlier maturing shorter staple types found in Georgia and Florida and designated as Westberry and Andrews sea island. Breeding work with sea island cotton, however, was not very effective in furnishing strains that would provide any assurance of a crop under heavy infestation of boll weevils. The rind of the sea island bolls is thin and is much more easily penetrated by the beaks of the weevils than is the case with the thicker walled carpels of the upland species. Also the sea island bolls remain subject to weevil injury during the entire maturation period, while upland bolls become relatively resistant to attacks after the third week of development. Moreover, the fruiting is not sufficiently early or uniform, and the period of boll development is too long to escape devastation by the weevil.

Selections From Acala and Lone Star

As previously noted, Acala S–5 was brought from the United States Cotton Field Station, Shafter, Calif., and grown on James Island. In 1927 selections were made from the Acala S–5. Several strains were developed as a result of this breeding and designated as Tidewater. Among those that have shown the best results are Tidewater 12, Tidewater 29, and a very long-fibered strain which was developed by J. C. Seabrook of Wadmalaw, S. C., in cooperation with the Department. Selections of Tidewater were made in 1929 from which a wilt-resistant strain has been developed.

It has been pointed out that Lone Star was developed by D. A. Saunders from a selection out of Jackson Round Boll. This variety has been maintained and further selected by the Department since Saunders introduced it. The work with Lone Star since 1918 has been carried on principally at the United States Cotton Breeding Station at Greenville, Tex., and since 1919 under the direction of H. C. McNamara. Commercial breeders have obtained stocks of this variety from time to time, some merely multiplying the stocks while others carried on further line breeding. The United States Cotton Breeding Station has several strains such as D–2, H. O. 2–5–1, P4–1. The D–2 line of Lone Star has provided seed stock for the present Gonzales one-variety community, which has about 75,000 acres of cotton in Gonzales and adjoining counties in Texas. There is also quite a large acreage of this strain in north Texas. Lone Star is the foundation stock for such cottons as Bennett, Paris Big Boll, Gorham, Russell Big Boll (not the parent of Columbia), Hasselfield Lone Star, Kinsler-Hartman, H–X, Lankart, Wacona, and Startex 619. It is also one parent of some varieties of hybrid origin, such as Stoneville cotton.

In addition to the actual development of improved sorts of cotton from imported and domestic stocks, Cook and his associates devoted much effort to studies of the morphological, heritable, and physiological behavior of the plant as influenced by acclimatization tests, by different regional effects in the Cotton Belt, and by adjustments to certain cultural conditions.[10]

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[10] From one or more of these standpoints, studies were made of wild forms, Hindi cotton, the diversity and the branching habit of Egyptian cotton, the general subject of the morphology of cotton branches, special morphology of branches and leaves such as dimorphic forms, arrangement of plant parts, supernumerary carpels, behavior of interspecific hybrids, kinds of hybrids in successive generations, mutative reversions and reappearance of primitive characters, suppressed and intensified hybrids, brachysm, physiological diseases and plant abnormalities caused by weevil damage, budding of incompatible species, abortive fruiting branches, weevil adaptations, transmission of various economic plant characters, and culture, especially spacing of the plants.

DEVELOPMENT OF AMERICAN-EGYPTIAN COTTON IN THE SOUTHWEST

Kearney's trip to Egypt in 1902 to study cotton culture there has already been mentioned. On his return in 1903, he and his associates made a concentrated effort to establish an Egyptian-cotton-growing industry in the irrigated districts of Arizona and southern California, where conditions were similar to those existing in the Nile Valley.

At first rather unsatisfactory yields and quality were obtained among the several imported varieties in the Southwest, but selection for better plants was continued. The persistent selection of the best plants gradually brought about some improvement in earliness, productivity, and quality of fiber, but not a great deal of progress was made until 1908, when two types were recognized and isolated from the Mit Afifi variety. These types were very different from the

FIGURE 17.—Field of Egyptian cotton at Sacaton, Ariz., 1913.

parental variety and represented a distinct step in the acclimatization of Egyptian cotton in the Southwest. One of the new types became the Yuma variety and the other the Somerton variety. The latter, however, was soon discarded because of its lateness and excessive vegetative development.

In staple length the Yuma variety averaged about 1⅞ inches. Field tests and also spinning tests of the fiber by manufacturers during the next few years demonstrated its suitability for commercial production. In 1912 the Department furnished seed to farmers for planting a few hundred acres in the Salt River Valley of Arizona and in the Imperial Valley of California. The acreage of American-Egyptian cotton in these areas increased rapidly during the next 5 years, and in 1917 production amounted to about 16,000 bales.

In 1910 a single plant of marked individuality was observed and selected from Yuma. The strain developed from this plant was named Pima. It was characterized by finer, lighter colored, and longer fiber than that obtained from Yuma. The staple averaged 1$\frac{9}{16}$ inches in length. After testing for several years it was concluded

that the new variety was superior to the parent, and Pima was substituted for Yuma. Ordinarily it is difficult for a whole district to replace one variety by another without considerable mixing of seeds, but the cotton growers of the Salt River Valley were sufficiently well organized to carry out the undertaking successfully. The entire acreage of American-Egyptian cotton was changed over to Pima in 1918, and 1920 saw the largest production in a single year—over 92,000 bales. A field of Egyptian cotton is shown in figure 17.

Another variety called Gila arose from a single plant selected by E. W. Hudson in 1908 out of the old, somewhat acclimatized stocks of Mit Afifi. This variety, however, did not gain much headway.

The success of the Durango and Acala upland varieties in the Imperial Valley of California brought competition with American-Egyptian there, and as far as commercial growing is concerned, the latter type has been confined entirely to the Salt River Valley of Arizona since 1921. After 1922 upland cotton also was introduced into the Salt River Valley and has been extensively grown, but through community effort the American-Egyptian stocks have been kept pure. As a result of the expansion of upland growing, the area devoted to the culture of American-Egyptian has declined. The area planted in 1935 was 38,000 acres, with an estimated production of 17,600 bales. Pima has been maintained as the sole variety until recently, but during the past 2 years a small acreage has been planted to a new hybrid variety designated as S×P 30 and developed from a cross of Pima and Sakel (Sakellaridis). According to both mill and field tests, it appears to be superior to Pima. At the present time back-cross work with this hybrid on both the Pima and Sakel parental lines is being carried on to obtain a higher quality of fiber as well as more productivity. A typical plant of Pima is shown in figure 18.

FIGURE 18.—A typical plant of the Pima Egyptian cotton grown at Sacaton, Ariz.

The work of Kearney and his associates from around 1900 to 1917 was confined to adaptation, breeding for improvement, and other research work connected with the culture of the crop. Since that period, a considerable part of their effort has been concerned with cotton genetics and a cytogenetic and taxonomic study of the cotton plant and some of its relatives. Many of these more fundamental problems presented themselves during the earlier period but were deferred because of the pressure of other needs. As a result of these researches, Kearney has become the leader in this country in the genetics of cotton and in the study of taxonomic relationships among the different species of *Gossypium* and some of their relatives.

Much of the benefit gained by bringing in new varieties and by the excellent breeding work that was done by the Department of Agriculture, private breeders, and the State experiment stations, has been

FIGURE 19.—A typical scene in the Cotton Belt of the United States, with lines of wagons loaded with seed cotton from a mixed-variety community awaiting their turn at the gin.

lost by the failure to perpetuate the best strains and varieties or to keep them free from admixture with inferior kinds (figs. 19 and 20). Realizing that this was a serious handicap to the whole cotton im-

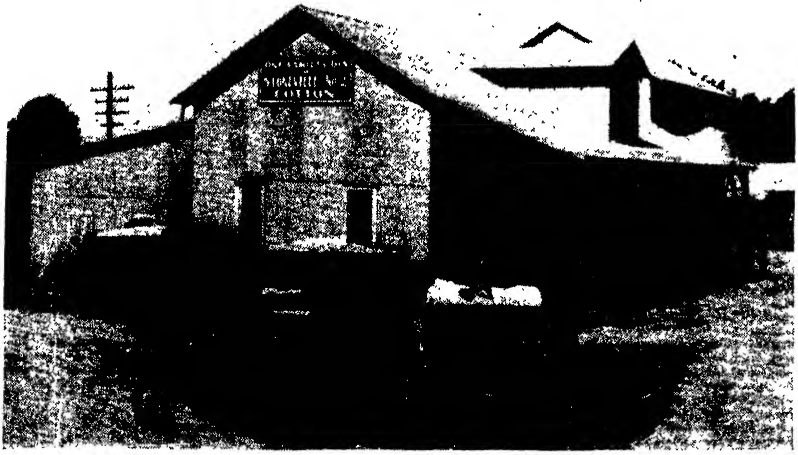

FIGURE 20.—Gin in the Orchard Hill community in Georgia, showing loads of seed cotton of one variety.

provement program, O. F. Cook proposed the one-variety-community plan and described the plan in an article published in the 1911 Yearbook entitled "Cotton Improvement on a Community Basis." The development of this plan by Cook's associates, in later years in coop-

eration with the Extension Service and the experiment stations in several of the States, has resulted in standardization of production of superior varieties and strains in many sections of the Cotton Belt. The first one-variety community began in 1912 with the distribution of the Yuma variety of Egyptian cotton in the Salt River Valley of Arizona. Two years later the North Carolina Agricultural Experiment Station began some work on a community basis. About the same time the growing of Durango was begun on a single variety basis in the Imperial Valley in California. After Acala became well established, about 1920, this variety provided seed stocks for one-variety-community work, especially in the Southwest. It practically supplanted the Durango there and was later designated by State law as the only variety that could be planted in certain sections of California.

Within the past 5 or 6 years the one-variety-community plan has been widely adopted and has resulted in keeping pure some of the best varieties produced by present-day breeders, and in their rapid increase. There were more than 300 organized communities in existence in 1935, planting nearly 800,000 acres in 156 counties and producing about 500,000 bales of improved community-grown cotton. Approximately 75,000 bales of one-variety cotton were produced in communities in Georgia alone. This type of organization fits in well with the cotton-breeding and improvement program because it facilitates keeping superior strains pure and increasing them rapidly so that they may be distributed over large areas at a minimum cost to growers. It is estimated that the better strains of the best varieties now in existence could be increased in this way to plant the entire cotton acreage of the United States within a period of 5 years. The uniformity produced by selected as compared to "gin-run" cotton is illustrated in figure 21.

A Historical Summary of Cotton Breeding at the State Experiment Stations

COTTON breeding for improvement in varieties at State institutions in the Cotton Belt was undertaken soon after State experiment stations were established, but new varieties were not produced until just after the turn of the century. The first breeding work done by land-grant colleges was in Alabama and Georgia, but the first varieties produced were at the South Carolina and Tennessee stations. At most of the stations breeding work did not begin until 1910 or later, and in a few States, in which cotton occupies only a small acreage, no program has been set up. These States have obtained their seed stocks from the more important cotton-growing areas where such work is carried on. The work in the States will be taken up in the order in which breeding efforts began.

Alabama

In 1886 P. H. Mell and C. L. Newman began to cross-pollinate cotton at the Alabama Agricultural Experiment Station. The following year this work was extended and a much larger number of

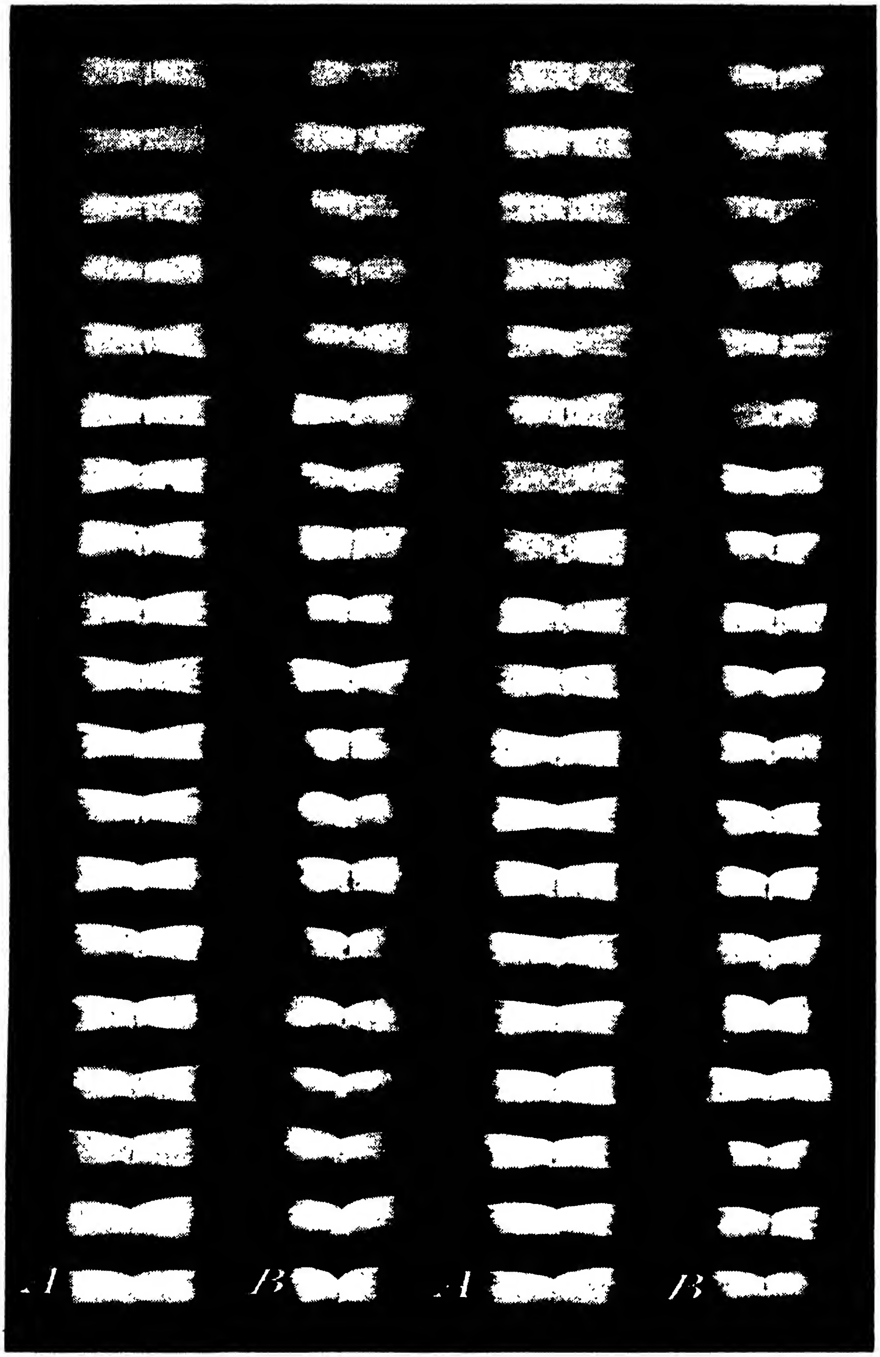

FIGURE 21.—Uniform fiber (*A, A*) combed on individual seeds from 19 consecutive plants in a row planted with pure seed of a select stock, compared with irregular fiber (*B, B*) from consecutive plants in a mixed, "gin-run" stock. Reduced.

crosses were made among several of the standard varieties of the period by Mell and E. R. Lloyd. Mell continued hybridization and the study of the resulting progenies for several years. Some of the crosses were sent to other experiment stations for testing, and one of these lots, sent to the South Carolina Station, was the stock out of which the Blue Ribbon varieties were selected later. In 1895 Mell began also to make crosses between several upland and several foreign varieties, but from the interspecific hybrids obtained no new varieties of any economic value were derived. J. S. Newman, while with the Alabama Station during this early period, carried on individual plant selection with the Peerless variety in order to purify it.

E. F. Cauthen worked with the station from 1908 to 1923. H. B. Tisdale became associated with Cauthen in 1914, working on wilt-resistant varieties as agent in cooperation with the Department of Agriculture from this date to 1920. Tisdale succeeded Cauthen in 1923, and has continued the station work in cotton breeding and improvement to the present time. About 1910, Cauthen began to select plants out of the Cook variety. Alabama Station Cook was the first strain produced; it had smaller bolls, higher lint percentage, and more uniformity than the original Cook variety. Cook 1010 was developed shortly thereafter; it had still smaller bolls, higher lint percentage, and shorter staple, and was very productive. Cook 307–6, introduced in 1913, is the parent of some commercial varieties, such as Rhyne Cook and the later wilt-resistant strains produced at the Alabama Station. A more recent wilt-resistant strain, Cook 912, developed by H. B. Tisdale, is rapidly becoming very popular in Alabama and is fast replacing other Cook stocks.

The cotton breeding and improvement program at the Alabama Station includes several newer strains of Cook and a Cook-Express cross which are being further line selected.

Georgia

Gustave Speth, horticulturist at the Georgia Experiment Station, made one of the first systematic and continuous attempts among experiment stations in the United States to improve the cotton plant by hybridization. P. H. Mell at the Alabama Station preceded him slightly. The crosses were between sea island and some of the upland varieties. The work was begun soon after the establishment of the station at Experiment, Ga., in 1889. A dozen or more hybrid lines were developed and while some of them were thought at the time to be quite promising, they finally failed, as have most later hybrids between these species. In 1893 H. N. Starnes, Speth's successor in horticulture, made crosses between several upland cottons, but the work was not carried far enough to establish and distribute new superior varieties. About the same time, J. M. Kimbrough, agriculturist at the station, began to select for improvement of the Jones Improved variety. This selection, doubtless the mass type, was continued for a decade or more. Early in the selection period, however, the stock of the reselected variety was introduced as Jones Re-improved, known after 1898 as the Schley variety.

After 1906, when the department of botany was established at the Georgia Experiment Station and R. J. H. DeLoach became botanist and pathologist, more comprehensive work in cotton breeding was undertaken by him and carried on for a number of years by his suc-

cessors. C. A. McLendon succeeded DeLoach as botanist in 1908 and occupied the position until 1913. He carried on the most comprehensive study in the inheritance of characters of the plant published in this country up to that time, 1912. (Ga. Sta. Bull. 99.)

The Georgia State Board of Entomology at Atlanta began considerable work in the study of the cotton wilt disease about 1905. This work was inaugurated by E. L. Worsham, State entomologist, and A. C. Lewis, assistant entomologist. As plant breeder for this board from 1916 to 1920, C. A. McLendon assisted in the work, but most of his time during this period was spent in testing and selecting varieties for boll weevil conditions in cooperation with individual growers in different sections of northern Georgia.

While at the Georgia Experiment Station between 1906 and 1908, DeLoach made some crosses among several varieties of upland cotton. Out of one cross between Cook Improved and Columbia, he later developed a variety, named Sunbeam, which was high-yielding and had large bolls, staple of about 1 inch, and some resistance to diseases. Further breeding work with the variety was carried on by DeLoach and later by Loy E. Rast, at Athens. From 1912 to 1914, Rast made further selections from Sunbeam that resulted in a new variety, College No. 1. In the variety tests from 1914 to 1920 inclusive, this was the earliest and highest producing variety out of about 40 tested. It soon became popular in some sections of the State where cotton wilt was not a serious factor, and because of its earliness was also a favorite for a while in a few sections in Georgia after the boll weevil became serious.

From 1915 to the present, the Georgia College of Agriculture has maintained the variety by continuous selection. Since Rast left the institution about 1918, R. R. Childs has handled the breeding and improvement work with College No. 1. In 1926 the selfing of strains was begun and carried through 1933. This work led to a variety much more uniform in staple length, which at present averages 1 to 1$\frac{1}{16}$ inches.

South Carolina

Probably the first cotton-breeding work done at the South Carolina Agricultural Experiment Station was started and carried on by J. S. Newman, who, while inspecting the progeny of an Allen Long Staple × Dickson cross, found an unusual plant which he marked by a blue band off a cigar. The selection was made about 1900 and the stocks, including several other cotton hybrids, had been sent to the station a few years previously by P. H. Mell of the Alabama Station. Newman, formerly from the Alabama institution, had been having these grown under his own observation.

The plant marked by the cigar band was picked separately, the seed was multiplied, and the stock was remembered as the Blue Ribbon variety. Out of some of the early progeny of the original Blue Ribbon plants a black-seeded variation was selected and developed into a second variety known as Black-Seeded Blue Ribbon.

The Blue Ribbon variety was a semicluster long-staple type, the cluster tendency coming from the Dickson parent and the long staple from the other parent—rather a distinct combination for a long-staple variety. The plants were medium to tall, abundantly fruited, compact, erect, with short joints, medium to early in maturity; bolls small, lint percentage 32 to 33, staple 1$\frac{1}{8}$ to 1$\frac{1}{4}$ inches.

Additional breeding work was carried on by C. L. Newman, the son of J. S. Newman, at the South Carolina Station a few years later. During the summer of 1906 C. L. Newman made a number of new crosses among some of the better upland varieties. In the winter of 1906–7 a larger number of standard varieties were collected, and these were tested in 1907 to determine their suitability for hybridization and also for line selecting. Crosses were made, usually between a short-staple and a long-staple variety, and from 300 of these C. L. Newman, J. N. Harper, and Burns Gillison selected 20 of the better appearing progeny rows in 1908. Several new strains or varieties were developed during the next few years from this hybrid work and from some of the older hybrids.

Out of the line selections, new strains of Wanamaker Cleveland, Toole, and Russell were derived. Tillman Pride came from a single plant selection out of Black-Seeded Blue Ribbon.

In 1911, H. W. Barre of the South Carolina Station, and his assistant, L. O. Watson, began cooperating with Orton and Gilbert of the Bureau of Plant Industry in breeding wilt-resistant varieties. Through the Pee Dee Branch Station at Florence and farmer cooperators, further improvement and distribution of the Dixie, Dixie-Triumph, and other wilt-resistant varieties were carried on. After Watson replaced Gilbert in the work in 1914, C. A. McLendon held Watson's position at the South Carolina Station from 1914 to 1916. After McLendon resigned in 1916 and Watson in 1920, breeding work was discontinued. It was realized that the several commercial breeders in the State were providing farmers with reliable and ample supplies of planting seed of all of the more suitable varieties, and the station therefore directed its efforts to solving other cotton problems. Since his resignation L. O. Watson has been a commercial breeder at Florence.

Tennessee

Cotton-breeding work at the Tennessee Agricultural Experiment Station in cooperation with the United States Department of Agriculture was begun soon after 1900 by S. M. Bain. An account of Bain's work has already been given.

Stocks of Trice, which was the variety Bain developed, were maintained under his supervision for many years by farmers who would observe the necessary precautions to keep the seed pure. After Bain discontinued his work, J. F. Bridger, of Bells, Tenn., preserved, grew, and distributed the variety until a few years ago.

Recently Newman I. Hancock and the late S. H. Essary of the Tennessee Station began some further work in breeding the Trice variety to preserve this stock and also to restore it to former uniformity and further improve its economic value. They developed Trice 5, Trice 25, Trice 5–42, and Trice 25–1–45. These men have also done some selection work with both the Acala 5 and the Acala 8 types. Acala has also been used recently in hybridization with the Stoneville type. One hybrid strain from a 1930 cross between Stoneville 2 and California Acala is in the process of development.

Texas

Heavy boll weevil damage in Texas before the spread of the insect to other cotton States made this State the first to start control measures. In addition to other remedies applied, the importation and

acclimatization of foreign kinds, and the introduction of varieties from other parts of the Cotton Belt were tried. Considerable work in varietal adaptation was undertaken by the Texas Agricultural Experiment Station. Beginning soon after 1900, R. L. Bennett of the Texas Station worked for several years with the variety problem in cooperation with the United States Department of Agriculture. All the well-known varieties from the earliest to medium early were brought in from the other cotton States and tried, along with those native to Texas.

During this period seed of small-boll short-staple varieties such as King, Sugar Loaf, and Simpkins were being imported annually in thousands of carloads to Texas, but they were very unsatisfactory to the cotton growers and buyers of the State. Bennett and other workers formulated ideas as to the best cotton to breed to meet the problem. The specification decided on was a short-jointed, big-boll, stormproof, medium-staple, early type with high lint percentage. This ideal served as a model for Bennett while he was at the station and also for the other cotton breeders who were working in Texas at that period.

While with the Texas Station Bennett began to select for more earliness from among the native Texas varieties. His first important selection was made in 1904 from Mebane Triumph. After 1908 this stock was planted as a new variety, referred to as the Bennett Selection. As a result of Bennett's work and that of the Department of Agriculture, and private interests, importation and cultivation of small-boll short-staple cotton in Texas was discontinued.

Shortly after Bennett left the Texas Station, H. H. Jobson took up the breeding work from 1911 to 1916 and emphasized inheritance studies with the object of obtaining information fundamental to breeding for practical ends. However, some of the branch-station superintendents continued the selection work for improvement alone. In 1916 E. P. Humbert continued Jobson's inheritance studies, and between 1916 and 1921 began the program of State certification and registration of cotton varieties. George F. Freeman, who was with the Texas Station in 1921 and 1922, also continued the inheritance studies and initiated plant-to-row breeding at the main station and several substations. This resulted in the development of a few new varieties or strains.

G. N. Stroman worked with the station from 1923 to 1925 but confined his attention mostly to a continuation of inheritance work, biometrical studies of certain characters in cotton varieties, and general variety testing. During this time the substation superintendents continued plant-to-row work.

Since 1925, D. T. Killough, formerly superintendent of substation no. 5 at Temple and later of the main station farm at College Station, has been in charge of cotton breeding and improvement for the experiment station. He has worked with several of the substation superintendents in developing varieties and strains by plant selection and by hybridization.[11]

[11] These varieties include: Belton 793; developed from Rowden; originated 1912 by A. K. Short while superintendent of substation no. 5, Temple. Belton 5984; improved strain also developed from Rowden; introduced 1920 by D. T. Killough, who at that time had succeeded Short; grown extensively for a period in communities in central Texas. Westex 8487; developed from Burnett by R. E. Karper, 1921. Mebane 804–14 and 804–53; developed from Mebane Triumph by R. E. Dickson. Startex 619; developed at College Station from Lone Star by D. T. Killough and G. T. McNess, 1927. Mebane 4120–140, 4120–141, 4120–153; developed from Mebane Triumph by J. R. Quinby, 1925. Mebane 804–50; developed from Mebane Triumph by D. T. Killough and R. A. Hall, 1927. Mebane 804–29 and 804–36; developed from Mebane Triumph; introduced 1927. Ducona; hybrid from Durango × Wacona; developed by D. T. Killough and D. L. Jones, 1927. Sunshine 10104–137–5 and 10104–114–3; developed from Sunshine by D. T. Killough and P. B. Dunkel, beginning in 1929.

D. T. Killough, W. R. Horlacher, and graduate students have done considerable work in cotton genetics during the last decade. They have worked on a number of plant characters and have also studied mutations induced by X-ray treatment.

Florida

About 1909–10 at the Florida Agricultural Experiment Station some work was done in the improvement of the Seabrook strain of sea island. New strains were developed by plant selection and distributed among sea island cotton growers of the State. In 1924 some hybrid work was started at the Florida Station. Many crosses were made between Council-Toole and Lightning Express, strain 3 and strain 4, with the object of obtaining an early wilt-resistant variety with improved staple.

In 1926, W. A. Carver planted F_2 or second-generation selections of the former set of crosses in a plant-to-row test and made some new selections from Carolina Foster and Cook 307–6. Hybrid strains were developed which possessed resistance to wilt and boll rot, were earlier and had a longer staple than the Council-Toole parent, and had a larger boll and a higher lint percentage than Lightning Express. Carver also continued progenies from selections from the three parental stocks entering the crosses and published some genetic studies of several characters in the upland species.

Breeding work at the Florida Station was discontinued in 1933 before the hybrid strains were ready for introduction. The two Toole strains have been introduced to farmers and grown to some extent in one of the counties.

Mississippi

Cotton breeding work was begun at the Mississippi Agricultural Experiment Station in 1911, when E. C. Ewing resigned from the Department of Agriculture and began work with the station. Ewing's first accomplishment at the station was the introduction and establishment of the Express variety, bred by D. N. Shoemaker in the Department of Agriculture. While an employee of the Department, Ewing had had an opportunity to observe the new variety where it was being tried in Texas in 1909 and 1910. It was not suitable for that State and was about to be discarded. It had occurred to Ewing, however, that Express would be splendid basic material for breeding a new type of long-staple cotton more suitable for boll weevil conditions in the Mississippi Valley than were the old late varieties. When he introduced it later, it became very popular and soon spread over the Delta and bottom lands of Mississippi and also extended into much of the alluvial lands of other Mississippi Valley States.

During the period of multiplication and spread of the original Express stocks, Ewing selected and developed new strains of the variety. The old stock had some objectionable features such as slender and long-jointed plants, low lint percentage, and some mixture of off types. The two best new strains selected were Express 350 [12]

[12] Express 350 was developed from a single plant selection made in 1913 and differed from the original stock in being a shorter, more compact, more uniform, and more prolific plant type. The staple length was about 1 3/16 inches and the lint percentage 28. Express 432 originated from a single plant selection made in 1914 and differed from the original stock in having a larger and more spreading plant; higher lint percentage, 31 to 33; shorter staple, about 1 1/8 inches; and more wilt resistance.

and Express 432. These have provided foundation stock for practically all later breeding with the Express type.[13]

In 1911 Ewing also obtained a sufficient quantity of the new Foster variety of cotton from the Department of Agriculture to plant a small field at the Delta Branch Station. Out of this field he made plant selections, and during the next few years two strains, Foster 11 and Foster 120, were developed from two plants taken in the 1911 season. The latter was a high-yielding strain and was distributed to growers. The former was discarded.

Selection work was started by Ewing with Lone Star in 1911, with Trice in 1913, and with Wannamaker-Cleveland some time during the latter part of the 1911–15 period. From the original selections of

FIGURE 22.—Cotton-picking scene in a field of Express cotton, taken in 1922 at Clover Hill, Miss., in the Yazoo Mississippi Delta.

Lone Star three strains, Lone Star 11, Lone Star 15, and Lone Star 132, were developed. One of the 1913 plants of Trice was the parent of what later became Mississippi Station Trice.

In 1915 Ewing began cotton-breeding work with the Delta & Pine Land Co. of Mississippi at Scott, Miss., and H. B. Brown succeeded him in the Mississippi Station work. On taking over the station work, Brown continued the cotton-breeding program of his predecessor. He completed the breeding work with the Express 350 and Express 432 strains and distributed the stock (fig. 22). He also continued to work with the Foster, Lone Star, Trice, and Wannamaker-Cleveland stock with which Ewing had begun to select breeding lines.

In 1916 Brown began selection work in a field of Foster 120 which resulted in the development of Foster 6102 and Foster 631. These

[13] The several Lightning Express strains, the Burdette Express, and Dortch Express came from Express 350. Express 121, Delpress 3, and Arkansas 17 came from Express 432. These Express strains and some of their derivatives have also been used extensively in hybridization with other varieties. Two other strains of this type, Express 15 and Express 122, selected by Ewing during the earlier years of his tenure with the Mississippi Station, have been important as parental material in the breeding of Salsbury and the Delta & Pine Land varieties. Express 15 was one of the parents of Salsbury and Express 122, a parental line from which Delta & Pine Land 3 is descended. Delta & Pine Land 3 was one of the parents of Delta & Pine Land 10, and Delta & Pine Land 10 one parent of Delta & Pine Land 11. Express 15 and Express 122 although of much value as parental material in hybrids, were never commercially important themselves.

were named Delfos (from Delta and Foster).[14] Each of the two Delfos types was superior to Express in several respects—They were more easily picked than Express and were higher in lint percentage than the Express 350 type. The Delfos 6102 type was the more popular. By 1925 the Delfos types had practically replaced the Express 350 type and also much of the acreage formerly in the Express 432 type. In most cases Delfos cotton has supplanted all other long-staple varieties in the Mississippi Valley and has been a strong competitor with this group of varieties in other sections of the Cotton Belt.[15]

In 1922 H. B. Brown became plant breeder for and partner in the Stoneville Pedigreed Seed Co. of Stoneville, Miss. After 1923 H. A. York became assistant to W. E. Ayres. Ayres, who had come to the branch station and taken over the long-staple breeding work in Mississippi at the Delta Branch Station at Stoneville in 1920, continued the development of the Delfos strains. York, however, has had the responsibility of this work himself since 1926. Certain strains of the Delfos 6102 type have been continued by the Stoneville Pedigreed Seed Co. and several other seed-breeding or growing firms. Both the Delfos 6102 and the Delfos 631 types have been used as breeding lines by H. B. Brown since he went with the Louisiana Agricultural Experiment Station in 1926.

In 1915 Brown selected plants out of the Station's Wannamaker-Cleveland stocks and developed from one of the original selections the Cleveland 54 strain, introduced several years later. From one plant of Lone Star 15, thought by Brown to be a hybrid stalk with Mississippi Station Trice and selected in 1916, he developed the Lone Star 65 strain, which was the parent of the Stoneville cottons later developed by Brown and others for the Stoneville Pedigreed Seed Co. In 1920 Brown selected plants from the Rowden stocks which he was carrying at the station, and one of these developed into the Station Miller variety. In 1921, Ayres, at the Delta station, selected plants out of Express 432 which resulted in the development of the Express strain 121.

J. Fred O'Kelly succeeded Brown at the Mississippi Station in 1922. He completed the development of the Station Miller variety, and from this in turn developed Miller 610. In 1930 a cross between a Miller strain and a Delfos was made, but the new hybrid variety has not been distributed as yet.

York, in addition to the work with Delfos and Missdel, has continued work with Express 121. In 1926 he isolated Delpress 3, named for Delta and Express.

The Delfos cottons have been the most important contribution in the cotton-breeding work done by the Mississippi Station. The strains produced by the Delta Branch Station are now designated as Missdel, from Mississippi and Delta.[16]

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[14]The plants of the 6102 type were smaller and more dwarf than were the plants of the Delfos 631 type. The former type was also more extreme in earliness than the latter. Delfos 6102 had a staple length of $1\frac{3}{32}$ to $1\frac{5}{32}$ inches, lint percentage 31 to 32, rather small bolls. Delfos 631 had a staple length of $1\frac{3}{16}$ to $1\frac{1}{4}$ inches, lint percentage 30 to 31.5, bolls intermediate in size and more storm-resistant than those of Delfos 6102.

[15]Later Delfos selections were: Delfos 910, out of Delfos 631 (1919); Delfos 911, out of Delfos 6102 (1919); Delfos 0556, out of Delfos 6102 (1920); Missdel 2, out of Delfos 6102 (1931) and Missdel 1 out of Delfos 631 (1922); Missdel 3, out of Delfos, 910 (1923).

[16]The Missdel strains with odd numbers originated from the Delfos 631 type and those with even numbers from the Delfos 6102 type. Strains of Missdel so far developed are Missdel 1 and Missdel 1 Wilt Resistant (Delfos 631 type); Missdel 2 (Delfos 6102 type); Missdel 3 (Delfos 631 type); Missdel 4 (Delfos 6102 type); and Missdel 5 (Delfos 631 type). Recently the cotton varietal standardization committee of the Association of Agricultural Workers and the committee with the same title of the American Society of Agronomy have decided that the strains belonging to the Delfos 6102 type should retain the type designation of Delfos and that the strains belonging to the Delfos 631 type should be known as Missdel.

Arkansas

About 1912 cotton-breeding work was begun at the Arkansas Agricultural Experiment Station by W. C. Lassetter and M. S. Baker. The early efforts were concerned with line studies of Allen Long Staple and Cleveland, and with crosses between these varieties. Some straight selection for improvement was also carried on with Trice, Cleveland, and a few other varieties. Trice selection studies were emphasized especially.

In 1915 Lassetter transferred to the extension service in the State, Baker resigned, and W. E. Ayres was appointed to do the cotton work for the station in 1916. In 1917 Ayres, in addition to the experiments that had been carried previously, began new work dealing with selections of Foster 120 for high and low oil and protein; Mebane Triumph for size of boll, length of staple, and lint percentage; and Express 432 for wilt resistance. Ayres was connected with the Arkansas Station until 1919, when E. A. Hodson took up the work and carried it until July 1920. During his tenure, Hodson published reports on the Trice studies and on some other phases of the cotton studies. J. O. Ware succeeded Hodson and continued with the station to 1935. Most of the studies inaugurated and developed by Lassetter, Baker, and Ayres were continued during the period of Hodson's and of Ware's tenure.

In 1921, selection work was started with Rowden, Acala, Meade, Lone Star, and additional strains of Express. Further investigations in cotton inheritance and in the genetics of the plant were also inaugurated. By 1923 and 1924 several new strains were isolated from lines of breeding material of the older work that had been carried by the station. These were Triumph 154, an early strain from the Mebane Triumph lines; Trice 323 from the old Trice lines; and Foster 140 from the Foster 120 oil and protein study lines.

During 1925, 1926, and 1927, new strains of the Rowden, Express, and Acala were isolated from the additional selection work started in 1921. These were Arkansas Rowden 40, Arkansas 17 (Express), and Arkansas Acala 37.[17] These varieties have become very popular in Arkansas, especially the Arkansas Rowden 40. This new variety has also spread to surrounding States to a considerable extent. Arkansas Rowden 40 is earlier and more uniform than the old parental Rowden variety, which was obtained from Rowden Bros., Wills Point, Tex. It has high quality, staple 1 to 1¹⁄₁₆ inches, big bolls, storm resistance, hardiness to drought, and considerable wilt resistance, and it produces high yields.

Since the three Arkansas Station varieties were introduced, a number of newer strains of Rowden and Acala have been developed by the station. Arkansas Rowden 2088, a strain selected out of Arkansas Rowden 40, and other newer Rowden strains are rapidly replacing this parental variety because it has somewhat deteriorated

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[17] Assistance was rendered by R. L. Dortch in helping to develop and distribute Arkansas Rowden 40, by Earl Kilpatrick in distributing Arkansas Acala 37 and other station strains, and by others who have multiplied station stocks. Arkansas 17 is a wilt-resistant variety, excellent for bottoms and the richer uplands—a staple 1⅛ to 1³⁄₁₆ inches, bolls larger than the old Express strains. The new variety is thought to have come from the Express 432 type, the stock of which had been obtained from the Delta Branch Station, Stoneville, Miss.; it resembles these stocks more than other lines from which selections were made. Arkansas Acala 37 is not wilt-resistant, but does well on both bottom land and upland where wilt is not a serious factor. It is more especially adapted to the northern parts of the Cotton Belt because of its earliness. The selections from which this new variety came were taken from a plot of Acala No. 5, the seed of which came from C. N. Nunn.

through segregation or mechanical mixture. Later strains are also replacing Arkansas Acala 37.[18]

The improvement work at the Arkansas Station was all done by the progeny-row method and a large number of later line-selected strains of Rowden, Acala, and Lone Star are undergoing strain tests at present. The line-selected stocks begun in 1921 were temporarily discontinued and stored in 1933.

The new varieties and strains developed by the Arkansas Station have reached the farmers through stocks grown by the Cotton Branch Station in Lee County near Marianna, and by several large seed growers. The extension service of the State was instrumental in popularizing the product of the station's breeding program among the farmers. As a result of this the quality of the crop in the State has been much improved in the last 7 years.

In addition to the breeding and improvement work at the Arkansas Station since 1920, several papers on the genetics of cotton have been published from material developed in the research program.

O. A. Pope joined the Arkansas Station staff in 1930 and has specialized in the study of cotton fiber with special reference to the breeding program. Several papers pertaining to this study have been published recently. L. M. Humphrey is at present in charge of the cotton genetics and breeding work at this station. Pope resigned in December 1935.

North Carolina

In 1914, when R. Y. Winters began cotton breeding and improvement work at the North Carolina Agricultural Experiment Station, he obtained two types of cotton, one a large-boll type, medium in time of maturing, and the other a small-boll early type. The former was Hope Mexican Big Boll, obtained from J. D. Hope of Sharon, S. C. In addition to having large bolls and medium maturity, this variety ranked high in yield, was easy to pick, had short staple of good quality, lint percentage around 35, and large, fuzzy seeds gray to brown in color. The small-boll early type was King, a variety grown extensively at that time in North Carolina.

Selfed lines from both types were developed and continued for a number of years and meanwhile a study of their relative stability through several generations was made. A few of the King strains were multiplied and distributed to some extent, but none turned out to be as satisfactory as the Mexican strains. Two of these, Mexican 6 and Mexican 18, were introduced to growers in 1920.[19] They have been widely grown in North Carolina. More recently selected strains are being developed to replace the older ones in case they should prove to be better or in case the older strains should begin to show deterioration. Mexican 87 has been developed from Mexican 18 and Mexican 128, and Mexican 58–14 from Mexican 6.

P. H. Kime, V. R. Herman, and S. W. Hill assisted Winters in the breeding program, and since 1925, when Winters became director of the station, Kime has had charge of the breeding and improvement work.

[18] The later strains of Rowden are Arkansas Rowden 4046, Arkansas Rowden 5056, etc. The newer strains of Acala are Arkansas Acala 34, Arkansas Acala 4067, Arkansas Acala 5119, Arkansas Acala 1114, and Arkansas Acala 891.

[19] These strains had been developed each from single plants by the plant-to-row and progeny test methods. They were similar in general appearance—medium-sized plants, early and prolific for a big-boll type, moderate-size leaves, staple 1 to 1 1/16 inches and of good quality, lint percentage 34 to 35.

Between 1916 and 1921, Winters, Kime, Herman, and Hill also carried on breeding work with the Cleveland variety. Several strains were developed from Wannamaker-Cleveland, and the more promising of these were turned over to the Edgecombe Seed Breeders Association at Tarboro, N. C. Through the assistance of Herman and later of Hill, both then employed as commercial breeders, these strains were preserved, multiplied, and sold to farmers from about 1921 to 1926.

Yield-test data from 111 tests conducted by the North Carolina Station for 17 years during the period 1915 to 1933 show the value of a breeding and improvement program to the variety situation in a State. In the tests, the acre yield of lint for the Mexican (station-bred) variety averaged 475.2 pounds as compared with 440.3 pounds for the unimproved varieties in use by farmers in the sections of the State where the tests were conducted. The acre value of the lint of the Mexican variety over this period was $121.24 and that of the unimproved varieties $106.11.

Spinning tests were also conducted for several years in order to compare station-bred strains with several other standard cottons. In one series of tests, the Mexican Strain 6 was compared with Acala 5 and 8, Lone Star, Rowden, Trice, Sugar Loaf, Cleveland, and a typical north-Georgia cotton. The fiber was spun into no. 28 yarn and broken. The yarn from the Mexican 6 strain proved to be stronger than that of any of the other varieties tested. In another breaking test, with no. 30 yarn spun from two crops in 1932 and 1934, Mexican 6–128 (station-bred) proved to be stronger than the other varieties, Acala, Coker-Cleveland 884–4, Farm Relief 1, and an Arkansas Rowden strain.

Oklahoma

The Oklahoma Agricultural Experiment Station began some plant selection and progeny row testing in 1914. A very early and well-adapted variety was much needed in Oklahoma at that time to cope with the boll-weevil problem. In the first year of the undertaking, a plant of early type was found by Glen Briggs in a field of the Mebane Triumph variety near Stillwater, Okla. Briggs was a senior student in the Agricultural and Mechanical College when he selected the parent plant. Doubtless this original plant was a natural hybrid with some local early variety that had previously grown near the Mebane Triumph parent material. From this, M. A. Beeson and Briggs developed a very early new variety designated as Oklahoma Triumph 44.

The variety has shown very desirable adaptability to Oklahoma conditions, both in the badly infested weevil areas of the southeastern part of the State and in the general area of the State toward the northern rim of the Cotton Belt. It has been widely grown, and for 6 or more years has occupied 300,000 to 400,000 acres in the State. A considerable portion of the stock used has not always been as pure as would be desirable because of the usual methods of handling seed stocks in such cases. On the other hand, several seed growers in the State have assisted in maintaining and distributing pure seed stocks, and some one-variety-community work has helped to keep it pure.[20]

[20] Since the introduction of Oklahoma Triumph 44, other strains, designated as Early Triumph, have been selected and propagated from this variety. Early Triumph 29 was introduced in 1923 and Early Triumph 32 in 1924. These newer strains were bred for more uniformity, especially in fiber.

From 1921 to 1926 Glen Briggs was in charge of the cotton breeding and improvement work at the station, and since the latter date L. L. Ligon has been in charge.

Some breeding work has also been carried on with selections from the Acala 5 type. A new strain of Acala 5, somewhat earlier than the parental material and designated as Acala 44, was developed in 1924. Some selections from the Acala 8 type and Arkansas Rowden 40 have also been made. The work with the former was begun in 1932 and with the latter in 1934. However, sufficient time has not elapsed as yet in the case of these last two cottons to obtain new varieties for distribution.

New Mexico

In 1923 a strain of Acala was introduced to farmers by the New Mexico Agricultural Experiment Station. Bred in California by the United States Department of Agriculture, the stock came from the

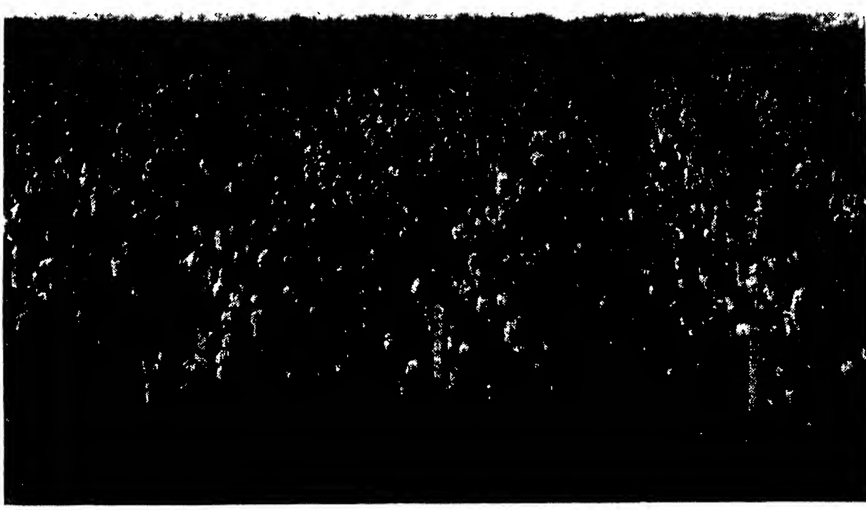

FIGURE 23.—Breeding block of Acala cotton, State College, N. Mex.

Acala 8 type and was designated as College Acala. In New Mexico the variety steadily increased, and in 1932 it occupied about 85,000 acres. It is still popular and continues to replace other varieties and strains of Acala. Since 1926, when the United States Acclimatization Field Station was established in the State, this station has cooperated with the New Mexico Station in maintaining seed stock of the variety for farmers.

In the fall of 1928 the New Mexico Station started an extensive project in cotton breeding, under the leadership of G. N. Stroman. The initial selections were made from College Acala and other stocks of the 5 and 8 types. Selections from other varieties were also made but were dropped after preliminary testing. Subsequently each year a few additional selections were made from some large fields of Acala in order to bring in new stocks that might have promise of superior performance (fig. 23).

The work has centered on a study of the breeding lines rather than an effort to hastily produce new strains for distribution. Pollination has been controlled from year to year in order to maintain the purity of the stocks. The progeny lines have been sorted on the basis of a comprehensive study of all the important economic characters involved, including seedling vigor, general plant type, earliness, yield, boll weight, percentage of lint, lint index, length of lint, and other fiber characters such as convolutions, diameter, and arrays.

Certain families in this series of Acala selections, particularly one designated as Family 504, have been isolated as having particular merit in possessing a large number of the desirable characteristics. The Pressley fiber sorter has been used to good advantage in isolating breeding lines at the New Mexico Station.

Louisiana

Systematic work in cotton breeding and improvement was not carried on to any appreciable extent in Louisiana until H. B. Brown joined the staff of the Louisiana Agricultural Experiment Station in 1926. In 1927 Brown started variety test work in representative sections of the State. He brought stocks of the breeding lines he had originated and continued while at the Mississippi Station and with the Stoneville Pedigreed Seed Co.—Delfos, Express, and Stoneville. Dixie-Triumph, obtained from L. O. Watson of Florence, S. C., and some of the Delta & Pine Land strains originated by E. C. Ewing of the Delta & Pine Land Co. of Scott, Miss., were also used as foundation stock by Brown. Since the same stocks were utilized, Brown's output has naturally blended with the introductions of the Mississippi agencies. In his regional variety tests, he found the strains of the Delfos, Stoneville, Express 432, Delta & Pine Land, and Dixie-Triumph types to be the lines of most promise for further breeding work in Louisiana.

Delta & Pine Land 4–8 was especially suited to the poor hill lands of northern Louisiana, where a vigorous, "rough-and-tumble" variety is needed to withstand the cultural hardships of the section. Its high lint percentage and hardiness probably came from the Mebane Triumph parent. Delta & Pine Land 10 was more prolific than Delta & Pine Land 4–8 and better suited to richer land, where it produced more than the older strain. The earliness and prolificness of Delta & Pine Land 10 are inherited from Express. The Express and Delfos types, especially the Delfos 6102, have been adapted more especially to bottom and other richer lands. The Dixie-Triumph variety was suited for areas infested with cotton wilt and it seems to resist more effectively than the other varieties some other common diseases, such as anthracnose, angular leaf spot, and rootknot. This type has the wilt resistance of the Dixie and the substantial hardiness, boll size, and lint percentage of the Mebane Triumph ancestor. The Stoneville strains, especially nos. 2, 3, and 5, had rather wide adaptation in the State except on some of the poor coastal plains and hill lands, where Delta & Pine Land 4–8 did better.

Express for a long period has been a very suitable cotton for lowlands because of its earliness and tendency to fruit under conditions conducive to overdevelopment of vegetation in most other varieties. The Delfos strains, especially the 6102 type, are well known for earliness and prolificness. These tendencies are perhaps results of mutation, as the ancestry did not show the traits in such a pronounced way.

The Stoneville cottons have earliness and prolificness, inherited from their Trice ancestry. The Lone Star ancestry provided inheritance in the Stonevilles for boll size, fair staple length, and medium to high lint percentage.[21]

In carrying out the breeding program, numerous plant selections were made from material grown in representative regions. These were tested in progeny rows, and strains from the better rows were tested for 2 or more years thereafter. The selected strains were increased in isolated fields and tried out in the variety tests in representative areas. This procedure is repeated with newly selected material from year to year or when it is desirable to supply additional breeding lines.

Numerous crosses have been made almost every year since 1926 to combine desirable characters or eliminate unwanted traits. As yet, new strains from this work have not been fully developed, but promising material seems to be present in some of the hybrid lines being carried. The straight-line selection work, on the other hand, has brought forth a number of strains and several of these have been distributed to the farmers of the State.[22]

Progress has been made in the variety situation in Louisiana. The staple has become longer and more uniform in length, and production has increased in comparison with that of former varieties. This improvement is due not only to introductions made by Brown, but to the more recent breeding work at the Louisiana Station. In 1932, 11 tests were conducted in various parts of the State. The average production of station strains and varieties in these tests was 357.9 pounds of lint per acre. The average production of varieties from other sources was 335.0 pounds per acre. The average production of the best station strain, which outyielded all the varieties tested, was 403.2 pounds. The leader and two others of the five ranking varieties in the tests were station selections.

Arizona

In Arizona in 1934 about 136,000 acres were devoted to cotton and about 28,000 acres of this were planted to American-Egyptian, a type heretofore described as bred and developed by the United States Department of Agriculture. Of the remaining 108,000 acres, about 97,000 were in strains of the Acala 8 type, and 11,000 acres in the Stoneville and Mebane Triumph types. The seed stocks of Acala originated in California at the Shafter and Indio United States Field Stations, and have been obtained from California growers and brought into Arizona from time to time by several cotton and cottonseed agencies.

The breeding work at the United States Field Station at Sacaton has been concerned almost entirely with American-Egyptian, but

[21] The Express strain introduced by Brown was Express 317, developed from the Express 432 type. This line has more wilt resistance, a higher lint percentage, and a larger boll than the old Express 350 type. The Delfos 631 type, represented by Delfos 2; the Delfos 6102 type, represented by Delfos 2323; the Stoneville strains 1, 2, and 3; some breeding lines of Dixie-Triumph; and some stock of Delta & Pine Land 4-8 also have been included in Brown's breeding stock at the Louisiana Station.

[22] These include: Express 070; from Express 317; developed 1930; now being introduced. Dixie-Triumph 757 and 759 (1927) and Dixie Triumph 85 (1928); from Watson's Dixie-Triumph; now being introduced. Delta & Pine Land 829; from Delta & Pine Land 4-8; developed in 1928 for northern Louisiana and now being increased there. Stoneville 022, from Stoneville 2; Stoneville 3-03, from Stoneville 3; 1930; now being introduced. Delfos 978 and 969 (1929); Delfos 032 (1930) and 130 (1931); from Delfos 2323; now being introduced. The Delfos strains of Delfos 6102 ancestry all resemble the original type in earliness and prolificness, which were very marked characteristics of that variety. It possessed these qualities in a much greater degree than any of its known ancestors. Apparently a new line of merit originated here as a mutant. It held its type for about 10 years and then began to vary, and the exact type disappeared. In 1931 a strain was isolated that is very much like the original Delfos 6102 type in characteristics. This is Delfos 2323-130 noted above.

some work has been done with Acala. However, no stocks of Acala have been generally distributed from this station. The Arizona Agricultural Experiment Station has done some work with the Acala 8 type, but none of the stocks has gone to farmers as yet. Through selection and progeny isolation, E. H. Pressley has a strain of Acala about ready for distribution. He also has a strain each of Stoneville and Mebane Triumph at about the same stage of development.[23]

Bryan about 1927 isolated a red-leaf strain of upland cotton which he developed from seed obtained from a farmer. The lint of this strain was very uniform, but the number of motes or undeveloped seeds was so great that it could not be used commercially. Bryan is also studying a cross between Pima and Tanguis (Peruvian) cottons. Fourth-generation segregates were grown in 1935 and certain of these combine the length of the Pima fiber with lint percentage approaching the high percentage of Tanguis. There is some promise that an improved long-staple variety can be established from the best of these segregates.

A Challenge to the Superiority of American Cotton

SINCE records of cotton varieties and strains have been kept, over 1,200 names have been listed as growing in the United States. Many of these so-called varieties, however, have been synonyms or new names applied to the same stock by different growers. A large proportion of the varieties listed at any period soon vanish, as is indicated by surveys made at a later period. Tracy stated that of the 58 varieties named in the Tenth Census report for 1880, only 6 were commonly in cultivation in 1895. These were Boyd Prolific, Dickson, Bancroft Herlong, Peeler, Petit Gulf, and Texas Stormproof. None of these is grown at present and most of them are extinct. Of the 118 varieties listed by Tracy in 1895 only 2, King and Truitt, were present in 1925. Tyler listed over 600 varieties in 1907. In 1925 not more than 25 of this list were in existence and only 9 were cultivated extensively.

A very high percentage of the varieties, then, come and go within a rather brief period, but a few lines seem to be continuous. The history of the leading varieties of today dates back over a considerable period and doubtless this period would be much longer if earlier records had been kept. It is evident from the preceding history that practically all the present upland varieties and strains originated from a few that were notable at various periods in the past century. Sea island apparently dates back to 1785. American-Egyptian dates back to a small patch of imported Mit Afifi grown in 1900 on the spot where Calexico, Calif., now stands. The development of Egyptian cotton itself dates back to 1820.

One of the chief factors contributing to the success of the upland cotton industry has been the absence of foreign competition. This

[23] The Acala strain has staple 1⅛ inches in length, lint percentage around 37, bolls about 60 to the pound. The Stoneville strain has staple 1 1/32 inches, lint percentage about 35, bolls about 60 to the pound. The Mebane Triumph strain has staple 1 1/16 inches, lint percentage about 39, bolls about 51 to the pound; this strain is characterized by very large bolls and high yields.

has now entered the picture in an intensified form. The trend of foreign cotton acreage and production for the past 45 years has been upward, but this increase abroad did not reach serious competitive proportions until after the World War, when the improved quality of much of the cotton grown outside the United States brought it into direct competition with American upland. The increasing volume of this better cotton abroad has been a result of various economic causes, but the actual establishment of the types has been made possible by the importation of American sorts, breeding them for climatic adjustment, and breeding and improving native kinds as well. The discussion of cotton breeding in foreign countries which follows describes this effort. World cotton production for the 10-year period 1924–25 through 1933–34 is shown in table 1.

TABLE 1.—*World production of cotton*

[10-year average, 1924–25 to 1933 34]

Country	Production, 1,000 bales of 478 pounds	Percentage of world production	Country	Production, 1,000 bales of 478 pounds	Percentage of world production
United States	14, 704. 6	55. 92	Uganda	162. 6	0. 62
India	4, 448. 0	16. 92	Chosen	133. 7	. 51
China	2, 150. 1	8. 18	Argentina	130. 1	. 50
Egypt	1, 522. 7	5. 85	Anglo-Egyptian Sudan	123. 8	. 47
Union of Soviet Socialist Republics	1, 274. 9	4. 85	Other foreign countries	549. 4	2. 09
Brazil	590. 8	2. 25	All countries other than United States	[1] 11, 591. 9	[1] 44. 08
Peru	246. 7	. 94			
Mexico	220. 9	. 84	Total world production	26, 296. 5	100. 00

[1] Computed from the figures in the table. Actual reported production was 11,569,700 bales, and actual percentage of world production, 44.00.

The most effective way to meet this competition is to sort out our own best lines, further breed and purify them, substitute these few good varieties for the many indifferent ones now used, and grow them according to environmental requirements through cooperation among the growers. The best American lines have been pointed out in what has already been said, many good examples of breeding have been cited, and the success of the one-variety-community plan has been shown.

In addition to the one-variety-community effort, there has been a step forward in the standardization of varieties. A committee of plant breeders and agronomists of the Association of Agricultural Workers, affiliated with the American Society of Agronomy, have chosen 31 typical varieties of the Cotton Belt as standard. Many of these varieties are represented by several strains. The list with the varietal description is published by H. B. Brown in the Journal of the American Society of Agronomy (vol. 28, no. 1, pp. 69–79, Jan., 1936). The list of varieties is as follows:

Acala–5
Acala–8
New Boykin
Cleveland–5
Cleveland–884
Piedmont Cleveland
Wannamaker Cleveland
Cook 307–6
Delfos
Delta & Pine Land–8
Delta & Pine Land–10
Deltatype Webber
Dixie-Triumph
Dixie–14
Express–121
Lightning Express
Half and Half
Kasch
Lone Star
Mebane
Missdel
Station Miller
Mexican Big Boll
Oklahoma Triumph–44
Pima
Rowden
Arkansas Rowden–40
Toole
Stoneville
Trice
Wilds

The Development of Cotton Breeding in Foreign Countries

THE period of cotton culture in the area of what is now the southern United States is only a brief span in history in comparison with the total age of cotton husbandry. Cotton improvement in the modern sense may not be much older in the countries where the plant is indigenous than it is in the American Cotton Belt. However, some crude form of seed sorting or selecting may have materially accelerated the adaptation of wild forms to domestication in the regions where the cotton plant was native; and later, man perhaps continued in a more systematic way to select the local stocks that best served his purpose.

After communication developed between the early cotton-growing centers, there was probably an exchange of material, and the plant also spread to new centers of civilization where it had not been known before. The exotic thus mingled with the indigenous, and unless the types were too remotely related and incompatible, crossing occurred and additional kinds evolved. Those carried to new situations also expressed new characters, stimulated or permitted to appear by the change in environment. In these ways, there must have been much sorting of the more adaptable kinds.

So much progress had been made in the evolution of the cultivated forms at the time when the first reliable records and plant descriptions were made that no relationship can be established with the present wild forms, nor can the prototypes of the current races be definitely surmised. Apparently cotton is indigenous only to certain tropical countries, where it is a perennial. On introduction to temperate climates, where overwintering was prevented by frosts, adjustment to the annual habit must have been partly effected by man through picking out the more suitable forms for propagation.

India is the oldest cotton-growing country in the Old World of which there is historical record. If the plant is not indigenous, cotton culture spread there at a very early period from Indochina and has persisted to the present time.

In Egypt cotton culture is comparatively a modern development and the crop has been made up of exotic kinds. Doubtless cotton first spread to Egypt from India several hundred years ago by way of the Indian Ocean and the Red Sea, or overland by caravans, or from Arabia, Iran (Persia), or some other near-eastern country where it had been previously brought from a point farther east. Such stocks were grown in lower Egypt in a small way until the nineteenth century. A fine quality of cotton had been grown in the upper regions of the Nile, particularly in Abyssinia, from time immemorial, and seed of this was brought to lower Egypt about 1820. Other modern cotton-growing countries in Africa, like the Anglo-Egyptian Sudan, Uganda, and many areas of less importance, may have had native cottons from the African center of origin, but their present industry is based on New World kinds.

Records indicate that the Chinese began to make extensive use of cotton fiber about 1300 A. D. The cotton grown belonged to the

Old World group and was probably introduced from India or Indochina at a period doubtless considerably antedating the fourteenth century. Previous to the fourteenth century cotton was used in China chiefly as an ornament.

The Union of Soviet Socialist Republics has developed into a modern cotton-producing country in recent years. Asiatic cotton was introduced into Turkestan, now part of the Union of Soviet Socialist Republics, many years ago, probably from Iran (Persia), where it had previously been introduced from India. However, the most rapid expansion in cotton culture in that country has occurred since the revolution and during the present political regime.

Chosen (Korea) and Manchuria have grown Asiatic cotton, introduced from other parts of China or India, for a long time, but only recently have they developed much of a commercial industry.

Cotton probably is indigenous to parts of Brazil, for European explorers found the Indians growing cotton there in the sixteenth century. This was doubtless in the tropical sections, where perennial cottons are still grown, and the region may have been part of the South American center of origin of cotton. However, the plant could have been carried there much earlier by roving Indian tribes from areas nearer the western part of the continent, which are more likely to have been the South American center of origin. Cotton was also found to be grown in Argentine by the first Spanish explorers, but doubtless it had been carried there at some previous time from the center of origin. Although the commercial crop of Peru and Mexico has always been small, these countries are probably situated in the two New World centers of origin.

COTTON BREEDING IN INDIA

For perhaps 4,000 years India took first rank among the cotton countries of the world. Throughout this period the crop was grown extensively and converted into sufficient quantities of cloth and various other fabrics to meet domestic needs and in addition to supply traders who carried Indian products to foreign countries.

Indian textile work was done, as much of it still is today, with hand-operated equipment, which is very crude and primitive. Doubtless much of the product consisted of coarsely fabricated cloths, cordage, strings, and other textile-like materials. However, the native artisans were able to weave muslins of such delicate texture that they have never been equaled in fineness, and the garments made from these cloths were sometimes referred to as "webs of woven wind."

The native cotton of India, so far as is known, has always been very short in staple length, often one-half inch and less. However, it is possible that some sort of fine or long-staple kinds of cotton were cultivated in that period but later became extinct. After the industrial revolution, the modern mill could not duplicate the fine work of the artisans of India with the short cotton. The advent of the machine stimulated the demand for cotton with more length and a more uniform quality in general. The factory interests turned to the United States for most of their raw materials—sea island cotton for the finest yarns, and upland for the general run of goods—until the cotton famine of the American Civil War, when they resorted to other countries temporarily. This situation again stimulated the cotton-

growing industry in India as well as in all countries where there was a possibility of expansion. The final result has been the marked increase in foreign production in recent years.

India now is second in production to the United States and produced during the 10-year period, 1924–25 to 1933–34, an average of 4,448,000 bales of 478 pounds, or 16.92 percent of the world crop. The trend has been distinctly upward for the past 35 years. Two things have made it possible for the manufacturer to utilize increasing quantities of Indian cotton: (1) The quality of the Indian crop has been improved by bringing in exotic kinds and by breeding, and (2) mill machinery has been adapted as much as possible to the utilization of a much higher percentage of the shorter fiber, which still represents a large percentage of the Indian cottons. The bulk of the Indian crop is estimated as still ranging from three-eights to seven-eights in length, but many of the short-staple varieties have undergone marked improvement through breeding during recent years. Some effort was made over a hundred years ago to improve the Indian cotton crop by bringing in exotic kinds, and the American upland cottons thus introduced have recently been used as breeding stocks. Other exotic types, including sea island and Egyptian, have not succeeded in India.

The Dharwar-American or Sawgined-Dharwar, which is grown in the Dharwar district located in the southern part of the Bombay Presidency of western India, dates back to 1819. At that time seed of American upland designated as New Orleans, a well-known commercial or trade type of that period, was imported and distributed near the town of Dharwar. Subsequently the East India Co. about 1840 made experimental trials in Dharwar and other districts of the Bombay Presidency with a number of foreign cottons, of which New Orleans, Georgias (upland), sea island, and Egyptian were the more important. The results of these trials indicated that the New Orleans type was the most suitable of the several kinds tested for the Dharwar area. It became very popular in the district, and about 1860 the plantings of the New Orleans cotton exceeded those of the native Kumpta cotton (*Gossypium herbaceum*).

The Punjab Province of northern India is at present the most important area in India for American upland. As early as 1825 seed stocks of both the New Orleans and Georgian trade types were carried to the Punjab from the Dharwar district. However, the droughts were too severe in certain years for the new kinds of cotton, and farmers continued to grow the indigenous or desi type, which was hardier. But fields of American cotton were grown here and there, and since crossing with the desi type did not occur, the American stock remained pure, perpetuated itself, and became more and more acclimated. This American stock became known as the narma (acclimated) cotton of the Punjab. Apparently the Georgian type persisted to a much greater extent than did the New Orleans type, probably because of the earlier maturity of the former.

An early effort was made to cultivate American upland cotton in what is now the United Provinces. The first undertakings were not successful, but further trials were started in 1870 at Cawnpore which terminated in the acclimatization of a variety known as Cawnpore-American. In the period immediately after the American Civil War a number of exotic cottons were brought in, including several types of American upland from other parts of India—such

types as Cambodia and a Georgian type, Buri. Since 1900 a number of upland varieties from the United States, some of which were highly productive, have been imported by the cotton workers of India, but none has succeeded without some years of acclimatization and reselection.

Experiments with exotic cottons in the Sind date from 1846, when Egyptian seed was tried at Shikarpur and sea island at Rohri. These trials were unsuccessful. From 1852 to 1854 sea island and New Orleans (upland) were again tried under the direction of an American planter without success. From 1868 to 1888 experiments with introductions were carried on near Hyderabad and Karachi which were rather inconclusive. These trials were both with American and Indian varieties.

Improvement in Modern Indian Cottons

The very short staple cottons of India, many of them one-half inch and less, and all less than seven-eighths inch, belong to the *Gossypium neglectum* and *G. arboreum* native species, and are cultivated in Central India, Central Provinces, Berar, Bengal, and Assam. This cotton is suitable for spinning counts from 1 to 16 and amounts to a little more than 3,000,000 bales, or about 70 percent of the total crop of the country. The medium-staple cottons from seven-eighths to 1 inch belong to three species principally—*G. herbaceum*, *G. indicum*, and *G. hirsutum*. The first two are native species and the last American upland. The medium-staple cottons are cultivated in Bombay, Madras, the Punjab, and Hyderabad. This cotton is suitable for spinning counts up to 22. The growth of the American upland stock is chiefly in Bombay and the Punjab. The medium staple amounts to somewhat over 1,000,000 bales, or practically 30 percent of the crop.[24]

Most of the breeding and improvement work in India has been done in the Provinces and districts, where the medium staples have been chiefly grown. The work has been concentrated on better staple, higher gin outturn, better yields, and disease resistance. Some work on staples longer than 1 inch with American upland long staple has been done, but such strains or varieties have not been distributed to any extent as yet.

Bombay has always been an important cotton-growing Province. Its acreage represents on the average about 29 percent of that of the whole of India. Real or systematic breeding and improvement work began in the Province soon after 1900, as it did in the United States. The publication of Mendel's and of Johannsen's studies had its effects in India too. From that period up to the present Mollison, Fletcher, Gammie, Main, Shevade, Kottur, Kulkarni, Patel, Mankad, Prayag, Thadani, Desai, and others have been associated with the breeding and improvement work.

Kumpta cotton—a trade type named for a port south of Bombay, including a series of more or less indistinguishable varieties of the *Gossypium herbaceum* species—was one of the first of the native cottons turned to by breeders in the first decade of the present century.

[24] The growth over 1 inch in length is negligible or amounts to not more than 0.1 to 0.2 percent of the crop. Very little cotton produced in India is suitable for yarn above a count of 22. These longer cottons are mostly of the American upland type. However, one native variety, Surat 1027 ALF, is capable of producing counts from 26 to 34. Both American upland and native stocks are used for breeding better types of cotton in India. Egyptian and sea island have been less successful. The use of the native tree cotton is rather unpromising because of the very mixed condition of the types and the greater danger of insect damage.

Mass selection for long and fine staple was begun at the Dharwar Farm in 1904. From this came Dharwar I and Dharwar II, the latter highly resistant to wilt. From a cross between these two came Jayawant, meaning victorious—a name justified by the yield, ginning percentage, staple length, and wilt resistance. Dharwar III was developed from a cross between two strains of Kumpta, and Dharwar IV from a cross between Ghogari (*G. herbaceum*) and Kumpta.

Gadag No. 1 was developed from the Dharwar-American grown in the Dharwar district for a number of years. This stock was first separated by Gammie into two types, hairy and glabrous, and later the hairy type was found by Kottur to be resistant to a disease known as red leaf blight. From this came Gadag No. 1, which at present represents the Dharwar-American in the district.

Banilla cotton originated from a cross of two native species, Bani (*Gossypium indicum*) with fine long staple and Comilla (*G. cernuum*) with high ginning percentage.

Surat 1027 ALF came from a cross between Ghogari and Kumpta, and it is now the longest staple native Indian cotton (1 inch or better).

In the Broach area of Bombay a wilt-resistant variety designated as BD8 (Broach, *Gossypium herbaceum* × Deshi 8, *G. neglectum*) has been developed.

In northern Gujarat some breeding work on the native Wagad (*Gossypium herbaceum*) variety was done—the bolls of this cotton only crack and the cotton is hulled out in the farmhouses—which resulted in Wagad 4 and Wagad 8, and work has been in progress recently to cross the Wagad strains with Surat 1027 ALF.

In the Sind the native cotton was found to be made up of several varieties of *Gossypium neglectum*—Rosea, Cutchica, Vera, and Malvensis. Rosea was found to be superior and through plant selection the strain designated as 27 W N was evolved. Selection work with the Punjab-American strains has been carried on, as well as selection with sea island, Egyptian, and fresh American upland stocks, and many crosses have been made. Among the strains already developed can be found those suitable for most purposes. These cottons are now being tested all over the area in well controlled experimental trials. Crosses have been made of Punjab-American cottons with sea island, with Pima (Egyptian), and with the American upland variety, Meade. The progenies are under study, and in addition to direct plant-breeding work, information of value as to the inheritance of certain characters has been obtained.

In the Punjab, in addition to the Punjab-American 4 F, developed out of the narma or old Georgian type and occupying 1,000,000 acres by 1924, two others of this type were evolved—Punjab-American 285 F and Punjab-American 289 F. Two improved native varieties have also been grown extensively—Mollisoni, a selection from *Gossypium indicum*, and Roseum, a selection from *G. neglectum*.

In several of the other Provinces of India cotton-breeding work has been carried on. Two upland types have been utilized, Cambodia in Madras, and Cawnpore-American in parts of the United Provinces. In these two Provinces, as well as in other political divisions of India, more useful strains from native sorts have been developed.

In recent years in India much emphasis has been placed on fiber quality and disease resistance. As a whole, the Indian cotton crop has been improved in quality to some extent, and in certain areas

where the breeding work centered and better means of distributing the new stocks of seed have been worked out, much advance has been made. The greatest improvement in staple length has occurred in the Punjab, where American upland varieties have received the widest distribution.[25] Several well-defined wilt-resistant varieties have been developed in India in recent years.

Plant breeders in India have to overcome many traditional ideas and customs, and to contend with poor ginning management, inadequate methods of seed distribution, and poor marketing facilities. In spite of this they have already made a distinct contribution to the Indian cotton industry, and they are now so organized that much more progress in improving the quality of cotton will be made within the next few decades.

COTTON BREEDING IN CHINA

China ranks as the third largest cotton-producing country in the world. The 10-year average production in bales of 478 pounds for the period 1924–25 to 1933–34 was 2,150,100. This was 8.18 percent of the world production. Not until the present century did the crop become commercially important.

Ever since textile products became a commodity in international trade, China has been a cotton-importing country. With the dense population, food crops are strong competitors of cotton. However, fuel is also scarce and some cotton is required for padding clothing as a protection against cold. The short Asiatic cottons served the purpose until China developed a textile industry in the nineties, when she began to need better cotton for manufacture. This was supplied in part by importations of American and to some extent Indian cotton. The development of the textile industry brought about the substitution of domestic for foreign goods, and the importation of raw cotton instead of textiles. The last step has been the effort to become self-sufficing in raw cotton. This has greatly stimulated cotton growing, and also improvement in quality. Much cotton of the short Asiatic type is still utilized domestically for hand manufacture and for padding clothing, but in the textile mills these native types are not suitable except for the coarse goods and wool mixtures. During the last 15 years, considerable effort has been made both to breed better native kinds and to introduce, adapt, and breed imported American upland varieties. China is on the way to supplying her own needs for cotton of the quality required by the native mills.

S. P. Peng, of the agronomy department, Nanking, writes as follows:[26]

> During the World War the cotton industry of China was given an opportunity to expand on account of the decreased world supply of cotton goods. On the other hand, the cotton mills found that the cotton produced inland did not meet their needs, either as to quantity or quality, so the improvement of cotton became of fundamental importance to the future of the cotton industry.
>
> Since 1915, the University of Nanking has undertaken experiments in cotton growing, particularly with reference to the introduction of American cotton, and has demonstrated the practicability of growing American cotton in the

[25] In 1915–16 about 80 percent of the total Indian crop was less than seven-eighths of an inch in staple length and the remaining 20 percent less than 1 inch in length. In 1923–24 the short staple amounted to about 67 percent and in 1933–34 to about 70 percent. None was estimated to be longer than 1 inch. In the last year or two staple longer than an inch has been reported and this is thought to have come from imported American varieties in the Punjab.

[26] In an article entitled "Acclimatized Varieties of Cotton—Trice and Acala," in Special Report No. 2, February 1935, College of Agriculture and Forestry, University of Nanking, Nanking, China.

vicinity of Nanking. Recognizing the importance of the cotton industry, the University has given much attention to the question of improved varieties. In 1919 a number of standard sets of cotton seed, representing widely different types of American grown cotton, were obtained from the United States Department of Agriculture, and variety tests were conducted in twenty-six centers, largely mission stations. . . .

During the year 1919, Dr. O. F. Cook, a cotton specialist with the United States Department of Agriculture, and Mr. J. B. Griffing, the head of the cotton work at the University, made a study in China on the behavior of both American and native cotton and on cotton problems in general. Some of their conclusions were as follows: (1) Trice and Acala, two acclimatized varieties, were fairly encouraging in the regions away from the coast and toward the North. (2) The superior strains of Chinese cotton in the lower Yangtze Valley indicate that there are great possibilities of improvement of the native stock.

With this in mind the University started a three-year program in 1920 in cooperation with the foreign cotton mill owners in Shanghai. . . .

Of the acclimatized strains, Acala and Trice, the latter was found to be especially good in the North because of its early maturity. The distribution of these acclimatized strains started in 1923.

FIGURE 24.—A row of an improved selection of Chinese cotton called "Million Dollar" developed at the University of Nanking, China. Grown experimentally in California for breeding and genetics studies.

Concerning the improvement of a native variety (fig. 24), Y. S. Chen, also of the agronomy department, Nanking, writes:[27]

The "Million Dollar" variety was developed from a boll found in a farmer's field near Woosung, Shanghai, by Mr. J. B. Griffing in the fall of 1919. Chinese farmers pick their cotton frequently, and this was the only boll left unpicked on the plant. Although the boll was four-locked, only three locks of cotton with a total of twenty-one seeds were obtained. The same year more than a thousand other specimens from individual plants were selected from different places. These selections were given careful laboratory study and 300 of the most promising were planted in the spring of 1920 in a large breeding plot. Here the plants of each progeny were kept from crossing by covering all the blossoms with paper bags. Of all the progenies so grown, three gave great promise from the standpoint of both yield and quality, and their seed was carefully multiplied in isolated fields in 1921. The most promising of the three proved to be the one given the name "Million Dollar" by the students . . .

Inasmuch as experiments show that Million Dollar is the best among the varieties of Chinese cotton which have been tested, and as the mills are willing to pay a premium of more than 20 percent for this cotton due to its superior quality, all the cotton experiment and extension stations of Chekiang Province are now using this variety for multiplication and distribution to farmers. This will continue until another superior variety is produced through the breeding work at the stations.

[27] In an article in the same report entitled " 'Million Dollar'—An Improved Variety of Native Cotton."

Little was known of the culture or use of cotton in Egypt until 1800, when a French expedition found two very distinct species of cotton being grown there. One was a tree cotton grown in upper Egypt and the other an annual cultivated in lower Egypt or the delta district. About 1820 the perennial kind, which may have been of African origin,[28] was transferred to lower Egypt. This marked the beginning of commercial cotton culture in that country. The perennial cotton soon replaced the existing annual form and the latter apparently became extinct in lower Egypt.

The introduced tree cotton in the Nile delta soon attracted the attention of the spinners of the world because of the quality of its lint. Production was fostered by Government control, and it became the characteristic type of Egyptian cotton. The success of tree cotton in lower Egypt led to the importation of stocks of American sea island, Peruvian, other kinds from the West Indies and South America, and possibly upland.

The brown, long, strong lint and the almost naked seeds produced by this former tree cotton were typical of commercial Egyptian cotton for a hundred years thereafter, and the present Egyptian cotton is still of the same general type with some variations in length and color of fiber. The present type, however, is an annual and is classified as *Gossypium barbadense*, a definitely New World species. When the imported New World cottons were grown in the same area with the tree type, they perhaps hybridized with the latter. Possibly this particular African form of tree cotton was genetically compatible with the New World introductions. The modern Egyptian annual (fig. 25) developed either through this hybridization, followed by selection, or it evolved through gradual change from the perennial to the annual habit, somewhat as sea island became adapted to the southeastern United States.[29]

From 1820 onward there was a gradual development of the cotton-growing industry in Egypt until 1861, when 150,000 bales of 478 pounds were produced. The cotton famine of the American Civil War greatly stimulated production, and in 1864 Egypt produced about 400,000 bales. With the exception of slumps after the Civil War and during the World War, production has been on the increase until the last few years. The 10-year average production in bales of 478 pounds for the period 1924–25 to 1933–34 was 1,522,700 bales, or 5.85 percent of the world crop.

Before the beginning of modern plant breeding, much improvement work similar to that of the American sea-island growers doubtless was done in Egypt. Since 1904 Egypt has utilized modern methods, and these have resulted in distinct genetic improvement.

Perhaps the first variety of the modern type recorded in Egypt was Ashmouni. This was supposed to have been one of the segregates of the crosses between the perennial and the annual types. The Ashmouni stock, from the village of Ashmoun, was a brown-linted annual

[28] It might have been carried to upper Egypt, to Abyssinia, or to the Sudan country by the Arabs or some other roving tribes from the East, or it might possibly have been of American origin and carried to Africa by some ancient seafarers.

[29] If the tree cotton was either Asiatic or African in origin and belonged to the 13-chromosome group of the Old World assemblage, it would not have been expected to cross with the subsequent introductions from the New World. The tree cotton was either of New World origin or it was a peculiar Old World type that was genetically compatible with the American kinds. After the new sort became adapted to the production of the Egyptian type of staple, apparently the tree form gradually became extinct.

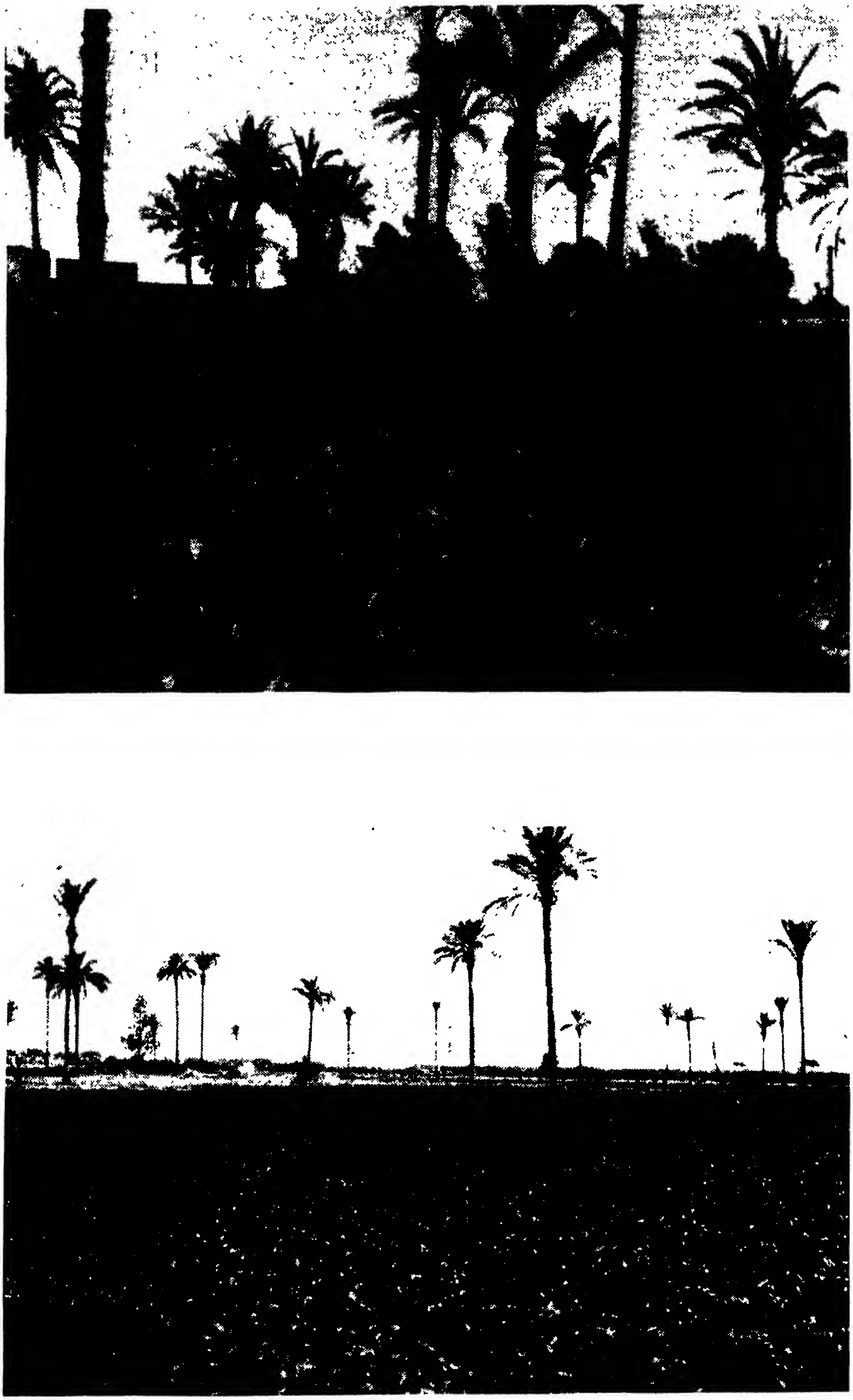

FIGURE 25.—Fields of Egyptian cotton in Egypt.

and has been referred to as old Brown-Egyptian. From the 1850's up to 1887 it was the principal variety grown.[30]

The Mit Afifi variety was developed from one or more plants found by a Greek merchant in Ashmouni stocks being grown near the village of Mit Afifi. The peculiar blue-green tufts of fuzz on the seeds of these plants attracted attention. On growing plants from these seeds, it was noted that the plants possessed decided advantages over the old Ashmouni cotton. The new type was developed and introduced commercially in 1887. It was an important variety in lower Egypt. The fiber was a richer darker brown than that of Ashmouni. It was long, very strong, and fine to the touch, and was in great demand for a number of years. Mit Afifi was also important as a parent of several later varieties. American-Egyptian was developed from it, and Dix-afifi, a Georgia wilt-resistant variety, came from a cross of Mit Afifi with the upland variety Dixie.

Because of the introduction of American sorts and the development of new variations out of the old hybrid complex, the Ashmouni stock was driven to upper Egypt, where it was reselected, purified, and again established with a new reputation.

Gallini, which is supposed to have had some Peruvian inheritance, was a very fine Egyptian cotton and controlled the fine-spinning market for a number of years, in the eighties and nineties. Abbassi, partly at least of sea island parentage, became a commercial cotton in 1893; Yannovitch, developed from Mit Afifi, in 1899; Nubari, developed from Ashmouni, in 1907; Sakellaridis or Sakel, in 1909; and Assili in 1910. The last two are supposed to have come from Ashmouni by way of Mit Afifi.[31]

Owing to the poorer development of irrigation in the upper Nile Valley and the virtual monopoly the long-staple Egyptian cotton enjoyed among the spinners of high-count yarn, the major part of the cotton crop of Egypt was grown in the delta, where this product of high quality could be produced to best advantage.

The Aswan Dam was built in 1903 and heightened in 1912. This greatly extended the cotton area now referred to as upper Egypt. The area is more suitable for growing staples of medium length. Since the World War the long staples, of which Sakel is the type, have not been in as much demand, many of the spinners finding that they can use an intermediate staple for much of the manufacture that formerly required the extreme lengths. As a result there has been a considerable demand for the staple length adapted for growing in upper Egypt.

In the market at present Egyptian cotton is referred to as Uppers and Lowers, from the upper Nile Valley and from the lower Nile Valley, though not all Uppers is grown in the upper Nile region. Uppers, which comprises the bulk of the Egyptian crop, is synonymous with Short and Lowers with Long in market parlance. Short-staple Egyptian cotton is longer than what is thought of as short staple in the United States. The length is from 1¹⁄₁₆ inches to 1⅜ inches. At this point the long staple represented by Sakel begins and

[30] Other varieties, later extinct, said to have developed out of the old hybrid stock were Gallini, Abiad Hariri, Bamia, Hamuli, Zahiri, and Sultani.

[31] Sultani and Valtos, Fathi and Charara were varieties of some importance in the nineties and the first decade of this century and were developed out of the old mixture of the two races. However, these disappeared some time ago. Sakel, grown in the delta or from Cairo northward, made up 77 percent of the Egyptian crop in 1921, and had replaced the older varieties, Mit Afifi, Abbassi, and Yannovitch. At that time Cazouli was a new variety similar to Sakel and was grown in lower Egpyt. In upper Egypt in 1921 Ashmouni produced 13.2 percent of the entire Egyptian crop and Zagora 7.2 percent.

runs up to $1\frac{1}{2}$ inches or slightly longer. During recent years, however, a class of intermediate staple lengths has been established in the Egyptian market.

Several strains of Sakellaridis have been established but they are all considered in the market as belonging to the Sakel type. They are rather specialized in their adaptation and confined to the lower sections of the delta. A fairly new variety called Maarad, developed from Pima (American-Egyptian), is adapted to a wider area than the Sakel and has a higher gin turn-out, a slightly longer staple, but is somewhat weaker and more irregular in length. In recent years Maarad has increased in popularity in the delta. Others of the newer varieties in the long-staple group are Nahda and Giza 7, which are somewhat shorter in staple, give better yields, and are adapted to a wider area. The better yielding varieties of late years have increased rapidly at the expense of Sakel. The leading varieties of the medium $1\frac{1}{4}$- to $1\frac{5}{16}$-inch staple are represented chiefly by Pilion and Fouadi, which were originated from the long-staple group. Grown in the lower Nile area, they also have been increasing at the expense of the Sakel type.

The chief varieties representing the short group are Ashmouni and Zagora, the former being grown in upper Egypt and the latter in lower Egypt. Between 1921 and 1935, the Sakel type decreased to 18 percent of the Egyptian cotton area, and Uppers—Ashmouni and Zagora—increased to 56 percent. The varieties of intermediate staple also became more widespread during this period. There has been a decided shift to shorter staples, and these have been bred for better yields. If well-bred varieties like Maarad, Giza 7, and Fouadi could be extended in the delta, and the improved strains of Ashmouni could be increased in upper Egypt, a considerable increase in the Egyptian crop would be brought about. Such a shift, however, will depend on the immediate demand for Sakel or other long-staple types and on efficiency in producing and distributing the newer varieties.

COTTON BREEDING IN THE UNION OF SOVIET SOCIALIST REPUBLICS

Cotton breeding and improvement in the Union of Soviet Socialist Republics has received considerable impetus in recent years. Until this effort became effective a considerable portion of the raw cotton for the Russian textile industry was imported. Outside of Transcaucasia, which is not particularly well adapted to cotton growing, Russia had no cotton-producing area until Turkestan had been conquered and taken into the empire about the middle of the nineteenth century. The cotton famine of the American Civil War stimulated cotton growing in the newly won territory and also to some extent in Transcaucasia.

Not much progress was made in obtaining suitable cotton from Turkestan and Transcaucasia until the short Old World sorts were replaced by introduced American upland varieties in the last quarter of the nineteenth century. During this period the development of railroads connecting the cotton regions with European Russia also materially aided both the expansion of cotton growing and the further development of the spindle capacity in Russian factories. Government aid was extended to farmers during a period before the World

War to encourage cotton growing. Plant breeders and other agronomic experts were also employed during this period to advise with the growers in handling and marketing the crop, and to breed the American upland varieties for better adaptation, better quality, and other improvements.

In 1915, 2,000,000 acres were grown, 88 percent of this in Central Asia (Turkestan) and the other 12 percent in Transcaucasia. This was the prerevolutionary peak year, and production was 1,500,000 bales of 478 pounds. The revolution brought a material falling off in production, but cotton growing took an upward turn again after 1922 and reached another high point of about 5,400,000 acres in 1932. However, since that year there has been some decrease, to 4,800,000 acres in 1934. Increase in total production has not kept pace with the enormous expansion in acreage. The acreage in 1933 was about two and one-half times as large as in 1927, but production gained only 70 percent. The 10-year average for the period 1924–25 to 1933–34 was 1,274,900 bales of 478 pounds, or 4.85 percent of the world crop.

There has been much effort on the part of the Soviet Government to increase yields and improve quality, but a great deal of this has been nullified by attempts to grow cotton in areas much less suitable to the crop than the old territory. However, in these new areas, which are in general north of the old belt and have a shorter season and a lower mean summer temperature, the present breeders have accomplished a great deal in breeding quicker growing and earlier fruiting varieties.

Replacement of Old World by New World kinds has been almost complete. The first attempts to introduce American cotton were made in Turkestan in the 1870's, with sea island cotton, but they proved unsuccessful. American upland, introduced during the next decade, was successful and soon practially displaced the Asiatic kinds. Practically all the Russian crop now ranges in staple length from ⅞ to 1³⁄₃₂ inches. The longer staples are due to the growth of Egyptian cotton.

With the reconstruction of the cotton-growing industry after political conditions became settled following the revolution, new varieties developed by Russian plant breeders, particularly the late G. S. Zaitzev and E. L. Navrotsky, were introduced on a commercial scale and soon became widespread. It has been estimated that the variety called Navrotsky, developed by E. L. Navrotsky from the American upland variety Russell, accounts for 70 percent of Russian cotton production at present. Strains of King, Mebane Triumph, etc., have also been adapted.

In the new cotton-growing regions only two rapidly maturing pedigreed varieties were to be planted according to the plan of 1934—Ak-Dghura No. 182 and Shreder No. 1306. In case of seed shortage a third, Dekkhan No. 169, was to be substituted. All three varieties have been developed within the past 20 years. The Soviet Government is now fostering a plan to grow the variety best suited to each region and to handle the seed stock in the best way from year to year.

Experiments with Egyptian cotton, begun in 1926 in Turkmenistan by the plant breeders Avtonomov and Krutzov, stimulated the introduction of this type of cotton on a commercial scale. In 1933 the area in Egyptian cotton was estimated at more than 160,000 acres, and in 1934 it was more than 250,000 acres. The most important

region for Egyptian cotton in the Soviet Union is Azerbaidjan in Transcaucasia. The Tadjik and Turkmen Republics in Central Asia are next in importance. Relatively little Egyptian cotton is grown in the Uzbek Rebublic, which is the most important cotton-producing region in the Union of Soviet Socialist Republics.

COTTON BREEDING IN BRAZIL

Cotton has been grown in parts of Brazil since European explorers found it there, but it did not gain much headway until the cotton famine caused by the American Civil War. The greatest impetus to cotton culture has come as a result of high prices of the commodity in relation to coffee and other products since the World War.

Up to recent times the cottons grown were the South America perennial types or Brazil tree cotton, and these types are still utilized rather generally in the northeastern commercial area. Toward the coast in this area, however, American upland has become established. On the other hand the present expansion of cotton growing in Brazil has come about chiefly through the introduction and successful adaptation of this annual form in the southern part of the country, where the crop had not been grown before.[32]

Rather early in the colonial period, around 1700, export shipments of cotton were made, and around 1775 spinning and weaving shops were set up in Minas Geraes, an area lying in what is classified as the southern region. Artisans from India were reported to have been brought by the Portuguese to teach their trade to the colonial mill operators. Not a great deal of expansion in either growing or manufacturing occurred until the American Civil War, when shipments of Brazilian cotton were said to have reached 368,000 bales of 478 pounds. However, after the cotton famine was over production in Brazil declined because of the low price of cotton from the United States, the competition from the growing of coffee, sugarcane, and rubber, and the freeing of the slaves in 1888.

With the decline of the rubber industry in Brazil in the early part of the present century, cotton culture began to come back. The World War brought higher prices for cotton, but the last few years have seen the greatest—and a rather unexpected—expansion. Over the 10-year period 1924–25 to 1933–34, the average Brazilian production was 590,800 bales of 478 pounds, which is 2.25 percent of world production. The estimated production for the year 1934–35, however, was 1,324,000 bales. This large increase occurred mostly in the southern States. During the 5-year period 1914–15 to 1918–19, only 20 percent of the average annual production occurred in the southern States, but in 1934–35 it was about 54 percent. Production in this area is chiefly in the State of Sao Paulo. Minas Geraes stands second, while much smaller amounts are produced in Parana and Rio de Janeiro. With the exception of some long-staple perennial cotton in Minas Geraes, the southern area is devoted entirely to the production of the upland varieties.

During recent years the Brazilian Federal Government and the various State governments have been active in the improvement of

[32] In the colonial period cotton was grown principally in the regions of Bahia, Pernambuco, and Maranhao, which lie in the northeastern part of the country between the mouth of the Amazon River and the port of Sao Salvador. The present northeastern area of cotton growing occupies this same section, with considerable expansion into adjacent States: Para, northwestward, toward the Amazon country; Piauhy, between Maranhao and Pernambuco; Ceara, Rio Grande do Norte, Parahiba, Alagoas, and Sergipe, toward the eastern portion of the continent. The northeastern-cotton growing area is north of south latitude 15° and more or less separated from the southern cotton-growing region, which is south of this latitude.

quality. This has been done partly by the importation of well-bred American varieties and partly by selecting and further adjusting their own varieties for local conditions. Government inspection and control of seed distribution has also been instituted. In 1932–33 the length of the staple of the Brazilian cotton crop according to estimates was distributed as follows: Less than 7/8 inch, 2.0 percent; 7/8 to 1 3/32 inches, 78.6 percent; 1 1/8 inches and longer, 19.4 percent. However, Brazilian cotton is somewhat less satisfactory in character than American of these lengths, doubtless partly because of poorer ginning.

There are several varieties of the tree cottons in Brazil and they apparently belong to four different species.[33] Very little or perhaps no work has been done with these cottons in the way of selection and pure-line production, or even precise classification of various botanical forms. They are in a hybridized state to a considerable extent, and much work is needed to separate them and properly develop them into high-grade agricultural varieties.

The Russell variety of Truitt origin apparently was introduced into Brazil soon after it was developed in the United States. It became the basic stock for much of the upland cotton of the South, which is the upland cotton area. Other American upland varieties imported by Brazil at that period and later were Sunbeam, Upright, Cleveland, Durango, and Webber. These have become hybridized and mixed among themselves, and some of them at least have been crossed either naturally or artificially with some of the native tree cottons. One of these interspecific hybrids is known as Herbaceo Verdao. It is a quick-maturing variety well adapted to the more rainy regions in the coast areas. Paulo Sousa and Nova Paulista are annual hybrid varieties that have been reported, but it was not stated whether they originated from crosses of perennial with upland or whether they came from crosses between certain of the upland varieties themselves. Carioba is a hybrid originating from Webber and Russell.

Until recently very little breeding and improvement work has been done in Brazil beyond some sort of crude selection of new types resulting from mixtures and hybridization, and the distribution of these stocks and the imported American kinds. During the last few years, particularly since the country has become much more interested in cotton culture, several undertakings following more systematic methods of breeding have been inaugurated to improve the crop. Along with the genetic improvement of the varieties, much attention must also be given to controlling the seed supply, and to improving general methods of culture and ginning, marketing, and transportation facilities.

COTTON BREEDING IN PERU

The use of cotton for the production of textile materials in Peru is indicated by specimens found in prehistoric ruins. Cotton plants noted as growing in that country by the early European conquerors and explorers belonged to the perennial tree type, and probably were descended from a type believed by archeologists to have existed sometime in the remote past. Through the period of settlement and until about 1860, the native cotton was used by the white settlers.

[33] Moco, Serido, and Sertao belong to *Gossypium vitifolium;* Rim-de Boi, Creoulo, and Maranhao to *G. brasiliense*, syn. *G. conglomeratum;* Verdao and Rigueza to *G. peruvianum;* Quebradinho and Braziliero to *G. purpurascens;* and Algodao, Ganga (wild cotton), Algodao Vermelho (red cotton), and Macao (trade name), to *G. mustelinum* species.

The cotton famine of the American Civil War induced the Peruvians to expand cultivation on an export basis. New varieties from the United States and Egypt were imported and tested. It was found that the native tree cottons were not so well adapted to commercial culture as the North American and Egyptian annual kinds. However, after a period of temporary success, the industry lagged and did not again become important until the present century.

For the first 7 years of the century the average annual export of Peruvian cotton was about 37,000 bales of 478 pounds. For the 5-year period 1909–10 to 1913–14 Peru produced an average of 106,000 bales. During the 10-year period 1924–25 to 1933–34 the average production was 246,700 bales, and in 1934–35 the production was estimated to be 398,000 bales.

The present Peruvian cotton industry was made possible largely by the introduction of sea island and Egyptian cotton and the breeding of new varieties from these to suit the soil and climatic conditions of the country. Pima cotton, bred for suitability to the irrigated valleys of Arizona and California, has also been found to be adapted in Peru. The most important contribution of plant breeding to the Peruvian cotton industry, however, was the development of the Tanguis, a wilt-resistant variety, in 1918 from possible hybrids with previously imported stocks. Of the 1933 crop it was estimated that 92 percent was made up of this variety, with Pima ranking second.[34]

COTTON BREEDING IN MEXICO

There is little information about cotton breeding in Mexico, and doubtless whatever improvement has come about has been through a primitive type of selection of the native varieties or through importation of improved varieties from the United States. Although Mexico is probably the original home of American upland cotton, only 220,900 bales of 478 pounds were produced on an average in that country during the 10 years 1924–25 to 1933–34.

Cotton for domestic use is grown on a small scale in widely scattered regions in Mexico but commercial production is confined to a few areas. During the 4-year period 1930–31 to 1933–34, the Laguna (Coahuila and Durango) district produced 60 percent, the Mexicali (Baja California) 16 percent, the Matamoras (Tamaulipas) district 10 percent, and the Juarez (Chihuahua) district 5 percent of the Mexican cotton crop. The other 9 percent of the crop may be assigned to less important widely scattered sections. Within the major areas given, the annual production fluctuates considerably, however, because of price changes and internal political conditions.

The commercial cottons of Mexico are of the upland type, with the better staple types in the Mexicali district and the medium to short staples in the other districts. The length of staple in the Mexican crop apparently averages better than it does in the Cotton Belt of the United States.

COTTON BREEDING IN ARGENTINA

Cotton was being grown in Argentina at the time of the Spanish conquest in the early sixteenth century, and it is supposed that the plant was introduced from Peru or Bolivia at some earlier period. Dur-

[34] Peruvian Full-Rough, Peruvian Semi-Rough, Egipto or Suave, Mit Afifi, and Sakellaridis each made up 1 percent or less of the crop. The origin of Mit Afifi and Sakellaridis of course are well known. The rough and semirough Peruvian varieties came from the native sort, while the Egipto or Suave is thought to have originated from American upland cotton introduced into Peru during the American Civil War.

ing the American Civil War, British spinners distributed cottonseed and ginning machinery in the Argentine. Following this, cotton plantations were established, but they were abandoned after the commodity could again be obtained from the United States. Because of high prices during and after the World War, the Argentine Government, with the aid of American experts, started the development of the present cotton-growing industry. The acreage planted in 1924–25 was 258,000 acres and in 1933–34, 482,000 acres. The average production over the 10-year period 1924–25 to 1933–34 was 130,100 bales of 478 pounds.

The territories of Chaco and Formosa, with small acreas in the Provinces of Corrientes and Santiago del Estero, comprise the cotton belt of Argentina. Chaco is the most important and has produced 90 percent of the crop in recent years. In the last year or two the acreage in Santiago del Estero has expanded considerably, however.

The cotton crop in the Chaco territory is made up of the so-called Chaco type. It is believed that this originated from some of the natural crosses occurring among the various types of American upland introduced in the early part of the present century. The variety is a hardy type but has been found to have a mixed staple from ⅞ to 1³⁄₃₂ inches. Out of this variety efforts are now being made to isolate and establish a uniform strain with longer and more uniform staple.

In the Province of Santiago del Estero a long-staple variety, presumably of the upland species, is produced. The commodity grown in this area is of high quality and is extensively used by Argentine tire companies. The type doubtless resulted from the introduction of improved upland long-staple varieties from the United States, or it has been developed by breeders in that country. Presumably all or almost all of the Argentine cotton crop is of the upland species.

COTTON BREEDING IN UGANDA AND THE ANGLO-EGYPTIAN SUDAN

Cotton as a commercial crop has been grown in Uganda for some 30-odd years and the acreage has increased from a little more than 42,000 acres in 1910–11 to more than 1,000,000 acres in 1934–35. The 1934–35 production was estimated at 200,500 bales of 478 pounds. The 10-year average production for 1924–25 to 1933–34 was 162,600 bales of 478 pounds. The rapid expansion of cotton culture in Uganda, a British protectorate, has come about through the efforts of the British Cotton Growing Association in cooperation with the local government. Experiment stations, railroads, and better facilities for marketing have been established. Both adaptation studies of exotic varieties and breeding have been carried on at the experiment stations.

The cotton grown in Uganda is of the American upland type, and the present varieties are mostly developments from stocks brought from the United States 10 or 15 years ago. The country has considerable variation in soil and climatic conditions, but through breeding and adaptation of these American sorts several varieties have been adapted, one or more for each of the chief producing areas. The staple of the crop ranges from ⅞ to 1¹⁄₁₆ inches in length.

The Anglo-Egyptian Sudan has been jointly controlled by Great Britain and Egypt since 1898. Cotton is probably indigenous, and if there was a center of origin in tropical Africa it may have been in

this part of the continent, or in some of the adjacent areas, such as Ethiopia (Abyssinia) or Uganda.

As a commercial crop, cotton has been developed in the Sudan since the British have had interests in the country. In 1910-11, according to estimate, a little more than 18,000 bales of 478 pounds were produced, but the industry did not become of much importance until after the World War. The 10-year average production for the period 1924-25 to 1933-34 was 123,800 bales. The largest annual production was in 1931-32, when the estimate was 206,000 bales.

In the Sudan, cotton is grown in six areas or sections under a variety of artificial and natural moisture conditions. The irrigated districts are Gezira, Tokar, and Kassala. The rain-grown cotton, which is unimportant, occurs in areas in the southern Provinces and in the Nuba Mountains. Since the Sudan is upper-Nile country, it is like Egypt in climate and soil, and much of the cotton acreage is planted to Egyptian Sakellaridis. American upland is grown only in the southern Provinces and the Nuba Mountains, where the moisture is furnished by rainfall, and in portions of the Nile Valley, where a pumping system is used. In this part of the Nile Valley, the temperature at fruiting time drops rather rapidly, causing a heavy shedding of fruit forms. Upland cotton seems to resist these conditions better than the Egyptian. The production of upland cotton in the Sudan has not exceeded 27,000 bales. The remainder of the crop is Sakellaridis.

The breeding and improvement work in the Sudan has consisted in the importation of varieties from Egypt and the United States, and in adapting these by selection and breeding to various localities or districts. There has been much effort to keep the seed pure by further selection and control of the seed supply on the farms. The cotton is marketed in the seed, and unless the seed cotton is carefully classified according to variety before ginning, this process mixes the seed stocks.

COTTON BREEDING IN CHOSEN AND MANCHURIA

Cotton growing in Chosen and Manchuria has been encouraged by the Japanese cotton spinners. Even before Korea (Chosen) was annexed in 1910 by Japan, cotton culture was fostered there by the Japanese. American upland varieties were introduced in 1906 and the production at present in Chosen from these stocks comprises about 75 percent of the crop. The American upland is cultivated principally in the southern half of the peninsula.

The staple length of the varieties from the upland stock ranges from ⅞ to 1$\frac{1}{32}$ inches. The native varieties, which comprise one-fourth of the Chosen crop, range in staple length from five-eighths to three-fourths of an inch in length. The American cotton is used for spinning while the native kind is used for domestically made textiles and the padding of clothing.

The cotton acreage in Chosen increased rapidly from 1910 to about 1925 or 1926, when the peak was reached. After that the acreage declined and then rose again after 1932, but the area occupied by the crop is not up to the 1926 level. Under the influence of the Japanese, some breeding work has been done, but even with this effort the upland cotton in Chosen is not equivalent in quality to that grown in the United States. The 10-year average production in Chosen for 1924-25 to 1933-34 was 133,700 bales of 478 pounds.

It is very recently that cotton production in Manchuria has been encouraged and expanded. This development also has been under the influence of the Japanese. In Manchuria 200,000 acres were planted in cotton in 1934 and 80,000 bales produced. About 60 percent of the crop is used for commercial spinning and 40 percent for bedding and the padding of garments. Only about 10 to 15 percent of the present production originated from American upland seed. Most of the area of Manchuria is too far north for profitable production of cotton. The plant is adapted to the southern part of the country only, and the native sorts, which are very early, do better generally than American upland.

At present organizations have been set up in Manchuria to improve the cotton industry through breeding better varieties both of the upland and native types, and to instruct the farmers in better cultural and marketing methods.

FIGURE 26.—Large perennial cotton plant on roadside in the town of Gressier, Haiti, West Indies.

OTHER DEVELOPMENTS ABROAD

Since the loss of the sea-island industry in the United States, the production of this cotton has been confined principally to the West Indies. One of the best cotton-breeding and cotton-genetic research institutions in the world has been established on the Island of Trinidad. The scientific and applied work in genetics carried on by S. C. Harland [35] and his coworkers at this institution is well known by cotton people all over the world. Especially in its more scientific aspects, this work serves the cotton interests of the whole of the British Empire wherever production is being attempted. A large perennial cotton plant in the West Indies is shown in figure 26.

The West Indies once produced a considerable quantity of commercial cotton. In fact, the industry began there before it did in the United States, but it was practically abandoned because of the competition of other tropical crops and the development of the American sea-island industry. After the latter succumbed to market de-

[35] Now General Genetics Adviser for the State of Sao Paulo, Brazil.

moralization and boll weevils, spinners turned again to the West Indies for long and fine fiber.

In the 40 to 50 other countries that grow cotton, including Manchuria, the 10-year average production from 1924–25 to 1933–34 was 549,400 bales of 478 pounds. Production in many of these countries is so unimportant, particularly for commercial use, that no attention has been paid to breeding and improvement.

The British Empire has been more successful in the development of cotton growing in her colonial areas than the other nations that hold possessions in potential cotton-growing regions of the world. As already noted, there has been much improvement in types and varieties in India, Egypt, the Sudan, Uganda, and the British West Indies through the influence of British manufacturing organizations.

Efforts are being made by the British to increase production in several of the less important cotton-growing countries in Africa. Belgium, France, and Portugal each have made some effort to grow cotton in their possessions in Africa, but not a great deal has been accomplished.

Appendix

Cotton Varieties and Strains Developed by Private Breeders in the United States

[Arranged in historical order, insofar as dates could be determined, except for certain groups listed under the name of a breeder or a locality]

Mexican: Brought by Walter Burling from Mexico City to Natchez, Miss., 1806. Introduced into South Carolina about 1816. Probably a big-boll type with short to medium staple. Considered by Tracy to be the stock from which most short- and medium-staple varieties have been developed.

Belle Creole: 1830–40. Originally in the hands of H. W. Vick, Vicksburg, Miss. Abundant lint; fiber long, firm, silky, soft, lustrous, oily; stalks large, tall, productive; bolls large, long.

Jethro: First recorded 1846. Developed by H. W. Vick from Belle Creole. Long staple; parent of Jones Long Staple, Six Oaks, and others.

Petit Gulf: About 1840. Originated by H. W. Vick. Plant large, straggling, late; bolls small; fiber 7/8 to 1 1/8 inches; gin outturn 30 to 32 percent.

Boyd Prolific: Reported as common in Mississippi about 1847. Developed from a plant found in a field of ordinary cotton by a Mr. Boyd. Described as semicluster, with short fruiting branches, irregular joints; bolls medium size; lint short; gin outturn 30 to 32 percent. Parent of Dickson and other varieties important in Southeast.

Wyche: Developed after 1853 by a Mr. Wyche in Georgia from seed sent from Algeria.

Jones Improved: Propagated by J. F. Jones, Hogansville, Ga., from Wyche, after the Civil War. Parent of Truitt, Russell, Columbia, Keenan, Hartsville, Webber, and one of the parents of Culpepper.

Dickson: About 1858. Developed by David Dickson, Oxford, Ga. Cluster-type cotton.

Bohemian or Supak: About 1865. Developed by a Bohemian settler named Supak near Austin, Tex. Bolls large, storm-resistant, but easily picked; staple about fifteen-sixteenths of an inch. Progenitor of Rowden and Express.

Griffin: 1867. Developed by John Griffin, Greenville, Miss., supposedly from a cross of an upland variety known as Green Seed and sea island. One of the best of the upland long-staple varieties before the boll-weevil period.

Parker: 1868. Originated by John M. Parker, Sr., Maxime, Miss. Parentage unknown. Bender type; fiber medium length, high quality, strong.

Bancroft Herlong: About 1868. Some seed sent by a Mr. Herlong in Alabama to the editor of the Southern Cultivator were turned over later to Edward Bancroft, Athens, Ga. After first trial, the variety was mixed with an early variety thought to be Dickson. Bancroft Herlong was developed from this mixture.

Peterkin: About 1870. Originated by J. A. Peterkin, Fort Motte, S. C. Resembled Rio Grande type; seed reported to have been brought originally by a man named Jackson from the back part of Texas. Considered preeminent for poor soil and hard growing conditions before the boll weevil period.

Dearing: About 1870. Probable originator, J. J. Dearing, Columbus, Georgia. Parent material not known. Object, high lint percentage (it is stated that 45 percent was attained). Short staple, resembled Peterkin.

Hagaman: About 1877. Selected by F. V. D. Hagaman, Jackson, La. Parent material probably a variety known as Deane. Plant rather large, rather late; bolls small; lint of good quality, length about 1$\frac{1}{16}$ inches; seed nearly smooth or sparsely fuzzy.

Keno: Probably prior to 1880. Also known as Mand Adkin, Eureka, and Colthorp. Originated by Mand Adkin, a Negro, by selection of best plants of common cotton for 3 consecutive years. Stocks later sold to A. S. Colthorp, Talla Bena, Madison Parish, La. Plants large, rather late; staple very fine, strong, silky, 1$\frac{1}{8}$ to 1$\frac{3}{16}$ inches in length. One of the most popular varieties.

Southern Hope: About 1880. Originated by F. Robiew, Louisiana. Parent seed said to have come from Peru. A good long-staple variety, length about 1$\frac{1}{4}$ inches. Around 1900, Marx Schaefer took up the growing and selecting of this variety for several years.

Cobweb: 1881. Developed by W. E. Collins, Mayersville, Miss. Reported to be a cross between the upland variety Peeler and an Egyptian variety. Plants of upland type, long limbs, late maturity, staple length 1$\frac{3}{8}$ to 1$\frac{9}{16}$ inches.

Welborn Pet: 1881. Developed by Jeff Welborn, New Boston, Tex. Said to be a cross or blend of Barnes (dense growing, broad leaf, green seed), Jones Improved, and Zellner (a very small clustered cotton probably developed from Boyd Prolific). Plants of cluster type, tall, slender; bolls medium size; lint short, about seven-eighths of an inch.

Drake: 1882. Originated by R. W. Drake, Greensboro, Ala. Selected from Peerless (semicluster type); resembled parent, but somewhat earlier and more clustered. Very popular in several States, especially Georgia and South Carolina, for a number of years, but rather susceptible to anthracnose.

Peerless: Prior to 1880. Originator unknown. Perhaps originated in Georgia. Parent of Drake and several other varieties. One of the best short-staple varieties for a number of years previous to 1900 and widely grown. Staple length seven-eighths to fifteen-sixteenths of an inch.

Jackson Round-Boll: 1897. Originator, James Jackson, Preston, Tex., by mass selection beginning 1882, followed by propagation of one ideal plant. Grown rather widely in Texas for a considerable period. Bolls large, storm resistant; plant vigorous; lint 35 percent; staple length seven-eighths to fifteen-sixteenths of an inch.

Braddy: 1884. Developed by L. C. Braddy, Little Rock, S. C., by selection from Simpson. Grown to a considerable extent in parts of South Carolina for several years. A short-staple variety, similar to those of the Peterkin group.

Cook Long Staple: 1884. Developed by W. A. Cook, Newman, Miss., from a single plant selected from a field of common cotton. Plant vigorous, late, much like Allen Long Staple; staple length 1$\frac{3}{8}$ to 1$\frac{9}{16}$ inches. A leading variety in the Mississippi Valley for many years.

Shine Early: About 1885. Originated by J. A. Shine, Faison, N. C., who considered it a hybrid between sea island and some short-limbed, cluster, upland variety. Plants tall, quite pubescent. Bolls small; locks fell out badly during wind and storms. Staple about seven-eighths of an inch in length.

Truitt: 1885. Developed by George W. Truitt, Lagrange, Ga. Objects—prolificacy, big bolls, and as much earliness as possible. Staple length seven-eighths to fifteen-sixteenths of an inch. According to the originator, Truitt was developed by selection from a variety known as Old Georgia White Seed. According to Tyler and Webber, the parent of Truitt was most certainly Wyche or some one of its derivatives. It seems likely to have been Jones Improved. The Old Georgia White Seed could easily have been from Jones Improved stocks.

Rogers or Rogers Big Boll: About 1888. Developed by R. H. Rogers, Darlington, S. C., by mass selection from a mixture of Jones-Improved, Bancroft Herlong, and another variety known as Jowers. Rogers giving his personal attention to the work each year for 15 years. Very desirable variety but somewhat late, an unfavorable characteristic after the arrival of the boll weevil. Semicluster in type. Bolls round with blunt apex, rather large. Lint about 32 percent, staple length seven-eighths to fifteen-sixteenths of an inch.

Culpepper: Developed by 1890. J. E. Culpepper, Luthersville, Ga. Possibly a hybrid between Wyche or Jones Improved and Dickson. A big-boll cotton

but plants somewhat semicluster in habit. Staple length, seven-eighths to fifteen-sixteenths of an inch, gin turn-out around 35 percent. Reported to have been more hardy than either parent except for anthracnose susceptibility (carried over presumably from Dickson). Staple reputed to be of better quality than Jones Improved or Dickson.

Cleveland: Came into prominence about 1890. Developed by J. R. Cleveland, Decatur, Miss., by 25 years of mass selection. Parent material not known. Not very uniform—plants both open type and semicluster. Bolls medium to large, little stormproofness, staple about fifteen-sixteenths of an inch. Reported to be early in maturity. Never distributed, but very important as parent of Wannamaker Cleveland, Piedmont Cleveland, and the other present-day Cleveland strains.

King or King Improved: About 1890. Originated by T. J. King, Louisburg, N. C. (later seed merchant at Richmond, Va.), from a stalk of very prolific cotton found in a field planted to the old Sugar-Loaf variety. Not very different from parent variety. King became famous as a variety and with Sugar-Loaf was widely used along the northern part of the Cotton Belt, and, for a period immediately after the incoming of the boll weevil, almost throughout the cotton-growing area of the United States. Both were short, early, wasty cottons, with very little storm resistance and small bolls. Now practically replaced by new varieties of better quality.

Jackson Limbless: 1894. Introduced by T. W. Jackson, Atlanta, Ga. Similar to Shankhigh in type. Plants much taller, fruiting zone higher from the ground than with most of the other cluster varieties. Bolls small, round, crowded together on very shortened branches. Staple short, about seven-eighths of an inch.

Hawkins: About 1895. Developed by W. B. Hawkins, Nona, Ga., according to Tyler, from a mixture of New Era, Peerless, Dickson, Bancroft Herlong, and some others. Plants fairly early; bolls somewhat clustered, medium in size; staple short, about seven-eighths to fifteen-sixteenths of an inch; lint percentage high for that period, around 36 percent. Grown widely over the Cotton Belt for a number of years.

Russell: 1895. Originated by J. T. Russell, Alexander City, Ala., from a single plant selection out of impure stocks of the Truitt variety. Considered by the originator a chance hybrid of Truitt with Allen Long Staple. This might explain the presence of long-staple plants found in the variety by H. J. Webber a few years later and developed into the Columbia variety. Plants large, vigorous; bolls large, with considerable stormproof tendencies; rinds thick and protective against boll weevil; fiber, 15/16 to 1 inch in length; lint percentage rather low for short cotton; seeds covered with dark-green fuzz which injured the linters sample and sometimes the lint sample, particularly if gins were adjusted to cut the seed close.

Toole: About 1895. Developed by W. W. Toole, Augusta, Ga., from a single plant selected out of a crop of Peterkin for its short joints and numerous bolls. Well adapted to rich, well-cultivated soil, not inclined to develop excessive vegetative growth. Plants somewhat similar to Peterkin but more inclined to semicluster habit. Bolls larger, staple somewhat longer—about fifteen-sixteenths of an inch. Apparently produced seeds pure for fuzz covering, whereas in Peterkin there was a tendency for some black or nearly naked seeds to occur. Noted for high lint percentage and a certain degree of wilt resistance. Parent of several later strains noted for wilt resistance.

Cook or Cook Improved: 1895. Originated by J. R. Cook, Ellaville, Ga., according to his statement, from a natural cross between a local Georgia variety known as Beat-All and a small-boll cluster variety thought to be Dickson. Intermediate in type between parents. High lint percentage, early in maturity, bolls medium in size, staple about seven-eighths of an inch. Not uniform, but served as parent material for other varieties, including Half and Half, Rhyne Cook, and a number of Cook strains selected by the Alabama Agricultural Experiment Station.

Coxe Yellow Bloom: 1896. A rather unusual variety in that it possessed petals clear lemon yellow in color and without spots. Developed by E. A. Coxe, Blenheim, S. C., from a plant thought to be a cross between sea island and the upland variety, Texas Wood (a synonym for Peterkin). Resembled the Peterkin type with the exception of the unusual bloom color. Bolls medium in size; lint percentage high, about 39 percent; staple short, seven-eighths to fifteen-sixteenths of an inch.

Boykin Stormproof: Probably in the 1890's or earlier. Originated by W. L. Boykin, Kaufman, Tex. Parent material probably Texas Stormproof (an older variety developed by W. J. Smilie of Baileyville Tex., which according to Tyler,

resembled Bohemian and Myers). Plants late, large, stocky; fruiting branches long and long-jointed; bolls large, protected from storm damage by turning down, by the shielding effect of the broad bur segments, and by the clinging together of the locks in one mass. Lint percentage moderately high, around 34 percent; staple variable but commercially about 1$\frac{1}{32}$ inches. With Texas Stormproof, has been grown widely in the Cotton Belt where these varieties were not too late in maturity for the locality.

Mebane Triumph: 1900. Selected and introduced by A. D. Mebane, Lockhart, Tex. Name given by Seaman A. Knapp. Mrs. Mebane, Paul M. Mebane, a brother-in-law, and W. P. Patton, Jr., a nephew (A. D. Mebane Estate), have continued the work since the originator's death in 1923. However, after 1929 Paul M. Mebane became plant breeder for the A. D. Mebane Cotton Seed Co., a separate firm located in Lockhart. This company has maintained its own stocks of Mebane Triumph since 1929 and in that year Paul M. Mebane selected an outstanding plant whose progeny provides the present seed supply. This strain was introduced in 1934. From 1907 to 1929 the A. D. Mebane Cotton Seed Co. grew and marketed seed which were from stocks provided by the originator, A. D. Mebane.

Allen Long Staple: About 1898. Developed by James B. Allen, Port Gibson, Miss. Extensively grown throughout the Delta of Mississippi and other long-staple districts until the boll weevil period. According to Allen, a cross between Yellow Bloom and Allen Hybrid, previously introduced by him, but of unknown parentage. (No connection has been traced between Allen Yellow Bloom and Coxe Yellow Bloom.) Plant rather tall, semicluster; bolls small to medium in size, seeds fuzzy and white, fiber very long and silky, about 1$\frac{1}{2}$ inches in length.

Sunflower: About 1900. Developed by Marx Schaefer, Yazoo City, Miss. Parentage unknown—original seed obtained from a local oil mill. Rather distinct in appearance from other sorts. About 10 days earlier than Allen Long Staple or Griffin; almost as early as King. Plants tall, pyramidal, with some tendency toward semicluster habit. Bolls small; lint percentage low; seeds fuzzy; staple very fine, long, silky, measuring about 1$\frac{3}{8}$ inches in length. Was grown to a considerable extent in the Mississippi Valley until replaced by better and subsequently bred varieties, and has been a parent of some of the important hybrid varieties.

Pride of Georgia: 1903. Originated by J. F. Jones from his older variety, Jones Improved. Inclined to fruit and mature earlier than parent; staple length about fifteen-sixteenths of an inch. Pride of Georgia was quite widely grown over most of Cotton Belt for several years.

Shankhigh or Upright: About 1904. Originated by M. L. Branch, Bishop, Ga., from a single upright type of plant found in his field of the Russell variety. Plants grow very tall, develop a long central stem with one or two large branches which also turn sharply upward. Bolls develop rather high on the stalk, are very round in appearance and of medium size. Staple seven-eighths to 1 inch, averaging about fifteen-sixteenths of an inch.

Half and Half.—Originated about 1904. Developed by H. H. Summerour, Duluth, Ga., from the Cook variety, by plant selection, plant-to-row comparison, and progeny strain testing. Plants medium early, rather compact; leaves only moderately abundant, of medium size; bolls medium size, rounded; fiber length, five-eighths to seven-eighths of an inch; lint percentage usually 40 to 46 percent. Came into prominence about 1911. Extensively grown in hill- and poor-land regions east of the Mississippi River. More recently, grown on corresopnding soil types west of the river, and in the short-cotton areas of western Texas and western Oklahoma.

Hibred: 1930. Developed by B. F. Summerour from a cross of Half and Half and Durango. Staple somewhat better than Half and Half but gin outturn somewhat lower. Grown to some extent in several States but not distributed extensively as yet.

Rowden: About 1905. Developed by Will Rowden, Wills Point, Tex. Stock originated from two bolls brought from the Sulphur Fork River bottoms about 50 miles northward and was thought to be of the Bohemian variety. The Rowden variety was bred by mass selection and kept reasonably true to varietal type by this method for many years. A large-boll variety. Has been widely grown in many areas in the western part of the main Cotton Belt, and is the parent of Arkansas Rowden 40, Hurley Special, Sunshine, and other later selected strains.

Wannamaker-Cleveland: Developed from the Cleveland variety by the plant-to-row method by W. W. Wannamaker, St. Mathews, S. C. Selection work started in 1908, but the new variety did not become prominent until 1916. Earlier, lower growing, more spreading, more prolific, with smaller bolls than the original Cleveland. Boll rounded, medium in size; gin outturn from 38 to 40 percent and sometimes higher; staple length, ⅞ to 1 inch. Widely grown for a number of years, but due to shortness of staple has now been practically replaced by more recently developed varieties. Parent of a number of varieties which have been derived either by straight selection or by hybridization.

Wannamaker-Cleveland Wilt Resistant: Developed from a single plant found in 1927 in the original Wannamaker-Cleveland variety. Thought to be a natural hybrid of the latter with Super Seven. Earlier, larger boll, higher lint percentage, longer staple than Wannamaker-Cleveland. Wilt-resistant; staple length 1¹⁄₁₆ inches, but many of the seeds partly devoid of fuzz. Introduced as a new wilt-resistant variety about 1931, but further distribution soon discontinued by the producer because of the presence of black seeds.

Wannamaker-Cleveland "Standard": A newer strain of short staple developed from the original Wannamaker-Cleveland variety, but being discarded by the breeder because of the shortness of the staple.

Wannamaker-Cleveland Staple: A new long-staple strain which is taking the place of all other Wannamaker-Clevelands. Said by the breeder to have the qualities of Wannamaker-Cleveland and in addition 1¹⁄₁₆-inch staple and wilt resistance. Sparse fuzz eliminated.

Dixie-Triumph Strain No. 1 (introduced 1931) *and Strain No. 2* (more recent): Developed by W. W. Wannamaker and said by him to have several improved features over the original Dixie-Triumph. Reported to be more prolific, earlier, of more compact form, with larger bolls and better staple.

Piedmont Cleveland: Developed by J. O. M. Smith and M. W. H. Collins, 1912 to 1919, and introduced to farmers in 1919. Has been very popular and widely grown. Resembled the parent Cleveland in habit but earlier, more uniform, more prolific. Stock has been kept fairly pure to the present time by renewal with strains developed later, but type has not been changed materially.

Strains introduced by the Bouknight Bros. of Johnston, S. C.: Dixie-Triumph Short Staple (1927), developed by B. B. Bouknight; Dixie-Triumph Long Staple, and Cleveland Short Staple (the latter from Wannamaker-Cleveland), developed by W. M. Bouknight; Cleveland Staple (from Cleveland 5) and Cleveland Big Boll (from Wannamaker-Cleveland), developed by J. H. Bouknight. The new Dixie-Triumph strains were the product of further selection from older stocks of the variety for wilt resistance, earliness, a particular fiber length, greater uniformity in general. The three Cleveland strains resulted from selection respectively for extra staple length, high lint percentage, larger bolls.

Marett Cleveland 5-5, Marett Cleveland 5-35, Marett Cleveland 6B-7—all from Wannamaker-Cleveland, and developed 1920 to 1925; Marett J. K., from Bottoms, developed in the same period, by the Marett Farm & Seed Co., Westminster, S. C. This firm also developed Dixie-Triumph 4 (1933), from the original Dixie-Triumph; Carolina Dell (1933), from Delta & Pine Land 4-8; Marett 100 (1926), from a cross of Marett J. K. and Delta & Pine Land 4-8. Objectives in improvement of the Marett strains and varieties—better yield, a staple length around 1 to 1¹⁄₁₆ inches, a high lint percentage. Dixie-Triumph 4 also selected for more wilt resistance. The plant breeders of the Marett Farm & Seed Co. are K. W. Marett, J. E. Marett, and W. T. McClure, Sr.

Woolsey Cleveland: Introduced about 1924. Selection begun in 1918 from Wannamaker-Cleveland by C. B. Woolsey, Aiken, S. C. Vigorous growing strain, productive, gin outturn 37 to 38 percent, staple ⅞ to 1 inch. Several additional strains of Woolsey Cleveland developed in recent years.

Wannamaker-Cleveland strains: Developed by J. E. Wannamaker & Son, St. Mathews, S. C., by selections beginning in 1917. First strain seven-eighths to fifteen-sixteenths of an inch staple, gin outturn 37 to 38 percent. More recent strains, ¹⁵⁄₁₆ to 1 inch staple. Two strains of Dixie-Triumph also introduced by this firm since 1932.

Dixie-Triumph 1, 9, 12, 25, 29: Developed by L. O. Watson. Among the more satisfactory of the present Dixie-Triumph stocks for wilt resistance and varietal utility in general. Watson Long Staple also developed by this breeder.

Strains and varieties developed by Coker's Pedigreed Seed Co., Hartsville, S. C.:

Hartsville: 1907. Breeding instituted by D. N. Shoemaker and W. C. Coker from Jones Improved. Development completed by D. R. Coker. Staple

length, $1\frac{1}{8}$ to $1\frac{3}{16}$ inches. Further improved by D. R. Coker and assistants through selection of 21 consecutive strains for uniformity of type, staple length (finally brought up to $1\frac{1}{4}$ to $1\frac{3}{8}$ inches), and quality. Discarded after 1922 because late maturity made the strain so subject to boll weevil damage that it would not survive.

Columbia: Distributed in 1907. Parent, a strain selected from Russell in 1902 by H. J. Webber, near Columbia S. C. Staple length $1\frac{5}{16}$ to $1\frac{3}{8}$ inches.

Webber 49 (1910) *and Webber 82* (1915)*:* Developed by progeny selection from seed obtained from Webber by Coker in 1907. Was developed into a strain uniform, productive, staple $1\frac{1}{4}$ to $1\frac{3}{8}$ inches. Webber 49, earlier, slightly the better staple, survived the boll weevil until 1928 and was selected through six consecutive strains. Webber 82 was selected through several consecutive strains, two of which were distributed but did not survive the boll weevil. However, Webber 82 was an important blood line and was the parent of Deltatype Webber.

Deltatype Webber: 1922. Selection from Webber 82–5–16 for earliness. Nine consecutive strains isolated, the last introduced in 1933. The best, most successful, most widely grown of the long-staple types produced by the Coker's Pedigreed Seed Co. through straight selection. Uniform, productive, splendid fiber quality, staple $1\frac{1}{4}$ to $1\frac{5}{16}$ inches. Important as a parent of more recent hybrid strains or varieties, the most important being the Wilds strains, which superseded the Deltatype Webber type.

Lightning Express: Eight strains developed, 1922 to 1932. Parent material, Express 28–350, obtained in 1917 from E. C. Ewing, of the Delta & Pine Land Co., Scott, Miss. All somewhat wilt resistant, but strains 5, 6, 7, 8 especially so. George J. Wilds, since 1922 head of the plant-breeding staff, has noted three forms of wilt in South Carolina, called the Hartsville, Sumter, and Manning forms. Lightning Express 8 is resistant to the first two, but slightly susceptible to the last. These strains were the most widely distributed Coker cottons from 1922 to 1928; grown all the way across the humid portion of the Cotton Belt. Early, prolific, staple $1\frac{1}{8}$ to $1\frac{3}{16}$ inches.

Super Seven: 1925. Several strains introduced over a period of years. Developed from a chance hybrid of Webber 49 and Dixie. Wilt-resistant, early, prolific, staple $1\frac{1}{16}$ to $1\frac{1}{8}$ inches. Widely grown for a few years but superseded by Clevewilt strains, more suitable general-purpose type.

Wilds: Six strains distributed, 1928 to 1935, from Deltatype Webber × Lightning Express, cross made by Webber and Wilds in 1919. Grown in Mississippi and Arkansas bottomlands and certain long-staple areas in eastern part of the Carolinas. The later strains are the longest type of upland cotton grown today. Significant as indicating the importance of hybridization for further improvement of the cotton crop.

Coker Cleveland 5 (1926), *Coker Cleveland 884* (1928)*:* Seven strains of the former and four of the latter distributed. Developed from Wannamaker-Cleveland by selection, plant-to-row and progeny testing, beginning in 1918. Objective: To provide varieties of intermediate staple length (1 to $1\frac{1}{16}$ inches) for general growing. Have played an important part—especially the Coker Cleveland 5—in improving staple length and quality of South Carolina crop; also used effectively in improvement programs of surrounding States.

Farm Relief: Three strains introduced, beginning in 1931. Developed by Wilds from strains of Cleveland crossed with strains of Lightning Express in 1921. Earliest and quickest fruiting of Coker cottons. Foliage thin, plant open, bolls large, lint percentage high, staple $1\frac{1}{32}$ to $1\frac{1}{16}$, quality excellent.

Coker Clevewilt: Five strains distributed, beginning in 1931. Developed by series of selections from progenitor line of Cleveland 884, repeatedly grown on wilt-infested land. Highly resistant to wilt—strains 4 and 5 resistant to Hartsville and Sumter forms, strain 5 thought to be resistant to virulent Manning form. Productive, staple $1\frac{1}{32}$ to $1\frac{1}{16}$ inches, gin outturn 37 to 38 percent.

Coker Foster: Six strains introduced, beginning in 1926. Five developed by pedigree selection from Delfos 6102, one (strain 4) from Delfos 631. Delfos seed obtained from H. B. Brown of the Mississippi Agricultural Experiment Station 1920. In the last decade some lines of Delfos 911 (6102 type) have been

ling fifteen-sixteenths to 1-inch strain, early and productive. Selected from Wannamaker-Cleveland in 1920.

Dixie 14: First introduced in the early 1920's. Selected from original Dixie; seven additional strains developed later. Objectives: Less clustered type than Dixie, earlier, better staple, more wilt resistance. Probably the most wilt-resistant of cottons, over a wide area. Whether they are resistant to all physiologic forms of wilt is not known.

Carolina-Foster: 1924. Selection from Foster 120, obtained from H. B. Brown of the Mississippi Station in 1920. Small early type similar to Delfos 6102.

Seven strains bred; from these Delfos 6102–38 and Delfos 6102–54 were isolated in 1926. Four strains from the former and three from the latter developed since 1926. Foster 13–46 Excelsior strains (from Carolina Foster strain 2), developed in 1930, is an outstanding long cotton. All Foster stocks early, prolific, staple 1 1/16 to 1 3/32 inches.

Delta 36: 1928. From Webber 82. Four strains subsequently developed. Long-staple type similar to Deltatype Webber.

Cleveland 52: 1928. From Wannamaker-Cleveland. Four strains subsequently developed.

Dixie-Triumph 4: 1930. From Watson Dixie-Triumph. Two strains with 1 1/16-inch staple developed later—Dixie-Triumph 44–12 and Dixie-Triumph 4–3.

Other important wilt-resistant varieties developed by private breeders in recent years:

Rhyne Cook: About 1921. A prominent variety, still grown on a very large acreage in Alabama and Georgia. Developed by the Rhyne Bros., Benton, Ala. Parent, Alabama Experiment Station strain Cook 307–6. Staple seven-eighths to 1 inch, gin outturn 36 to 40 percent, boll size 70 to 80 to the pound; easily picked, high yield, marked wilt resistance. In recent years C. L. Rhyne, Americus, Ga., has continued Rhyne Cook by mass selection.

Bottoms: About 1915. Developed by A. T. Bottoms, Athens, Ala., from a Texas variety, probably Mebane Triumph. Dwarf type, semicluster, extra early, fast in fruiting, bolls of medium size, staple length seven-eighths to 1 inch. Did not become very prominent.

Rucker: Developed 1912 by Rucker Bros., Alpharetta, Ga. Parentage, an accidental cross between King and Cook. Rather extensively grown, especially in Georgia and Alabama, but now largely superseded by more recent varieties. Rucker No. 11, introduced in 1931, is thought to be a natural hybrid from the original Rucker and one of the Webber strains. Within the last year or two popularity has waned somewhat.

Addison: Originated by W. P. Addison, Blackwell, Ga., perhaps from Half and Half. Grown to a considerable extent a few years ago in Georgia but at present less popular.

Sikes Early Big Boll (probably from Wannamaker-Cleveland), *Sikes No. 7, and Sikes Wilt Resistant* (probably from Dixie-Triumph): The Sikes varieties occupied a moderate acreage in Georgia from 1928 to 1934.

Covington-Toole: 1900–1910. Developed from Toole by W. F. Covington, Headland, Ala.

Mathis-Toole: 1900–1910. Developed from Toole by W. J. Mathis, Dawson, Ga.

Perry-Toole: 1900–1910. Developed from Covington-Toole by J. P. Perry, Dawson, Ga.

Petty-Toole: 1900–1910. Developed by H. A. Petty, Dawson, Ga.

Brim-Toole: 1900–1910. Developed by J. E. Brim, Dawson, Ga.

Council-Toole: 1900–1910. Developed by M. B. Council, Americus, Ga.

Sam Wood: 1900–1910. Developed by Samuel Wood, Abbeville, Ala.

Strains and varieties developed by the Delta & Pine Land Co., Scott, Miss.:

Salsbury: Developed 1916–22. Product of a single cross of an extra early, prolific Wannamaker-Cleveland plant as female and one of the best Express 15 plants as pollen bearer. Quite early, bolls medium size, staple 1 1/16 inches, gin outturn 31 to 34 percent, highly disease resistant, one of the best yielders of its time. Widely grown over the humid part of the Cotton Belt until replaced by more recent improved varieties.

Delta & Pine Land 4 and Delta & Pine Land 8: Developed 1917–25. Product of a Polk (long-staple local variety) by Mebane Triumph cross. Even more popular and widely grown than Salsbury during the period 1928–32. Now discontinued by originator but still survives in many places. High gin outturn, hardy, high yield, moderately early, boll medium size, staple 1 1/16 inches, fairly disease resistant.

Delta & Pine Land 6: Developed 1919–27. Derived from a single cross of Express 122 and a strain of Foster 11 (sister selection of Foster 120). Never widely grown, occupying only few thousand acres in 1928 and 1929. Early, very disease resistant, productive, gin outturn high for the length of staple, staple 1 1/8 to 1 3/16 inches. Did not become widely popular because of small, tight, pointed bolls. Discontinued several years ago.

Delta & Pine Land 10: Developed 1919–27. From a cross between an unnamed noncommercial hybrid and an Express selected line. One of the most productive strains introduced in the Cotton Belt. Early, staple 1 1/16 inches, boll medium size, gin outturn 33 to 37 percent, moderately wilt-resistant. Still widely grown in the humid parts of the Cotton Belt.

Delta & Pine Land 11: Developed 1928–34 from a cross between Delta & Pine Land 10 and an unnamed noncommercial hybrid. Outstanding for high lint percentage (37 to 42 percent), slightly longer staple. Early, staple 1 1/16 to 1 3/32

inches, boll medium size, fairly disease-resistant, perhaps more productive than Delta & Pine Land 10. Rapidly gaining popularity in many areas since its recent introduction.

Delta & Pine Land 11A: A selection from Delta & Pine Land 11 for more uniformity and a slight increase in staple length. Not yet distributed among growers but will replace its parent strain on properties of originator in 1936.

Strains developed by the Stoneville Pedigreed Seed Co:

Stoneville 1, Stoneville 2: Developed 1923–28 and introduced commercially in the latter year. Widely grown; Stoneville 2 popular in Georgia as stocks for one-variety community production. Staple 1 to 1 1/16 inches, high lint percentage, easily picked, unusually productive. Selected from Lone Star 65.

Stoneville 3: Developed 1925–30. Selection from Stoneville 2. Earlier but not especially superior to parent. Used as the breeding line for Stoneville 5.

Stoneville 4: Developed 1926–31. An improved selection of Stoneville 1, which it replaced on the originator's farms in 1933. Larger boll, better lint percentage, higher productivity, more uniformity in general.

Stoneville 5: Developed 1927–32. Selection from Stoneville 3. One of the best Stoneville strains for high lint percentage.

Stoneville 2A: 1928–33. Selection from Stoneville 2 for larger bolls, more uniform fiber of better quality. Replaced Stoneville 2 on the originator's farms in 1932.

Stoneville 4A: Developed 1929–33. Selection from Stoneville 4, representing further improvement over parental line in boll size, lint percentage, ease of picking, uniformity of fiber.

Delfos 324: Developed from Delfos 6102. Plant selected in 1923 but strain never introduced commercially. Seed stocks lost in the flood of 1927. Larger bolls, longer fiber than parent.

Delfos 531: Developed 1925–29. Selection of Delfos 6102. Higher lint percentage, longer fiber, greater productivity.

Delfos 719: Developed 1927–32. Progeny line of Delfos 324, substituted for it after the latter was lost. Bolls larger, rounder than parent, lint percentage higher, fiber shorter but of better quality.

Delfos 531A: Developed 1928–32. Selection of Delfos 531. Higher lint percentage, longer fiber, greater productivity.

Delfos 89 (developed 1928–33), *Delfos 9252* (developed 1929–34). Selections from Delfos 324 for larger boll, longer fiber, better picking quality.

Strains recently developed by private breeders in Arkansas:

Burdette Express (from Express 350), *Burdette Lone Star* (from Lone Star 65), *Burdette Trice* (from Mississippi Station Trice), *Burdette Acala* (from Acala 8), *Burdette Delfos* (from Delfos 6102): Developed by the Burdette Plantation, Burdette, Ark.

Roldo Rowden 40-2-9: Developed from Arkansas Rowden 40 by Robert L. Dortch, Scott, Ark., in cooperation with Arkansas Agricultural Experiment Station. Roldo Rowden 40–9–F–6–3–1 more recently developed by Dortch.

Acala 37-6: Developed from Acala 37A by the Loy E. Rast Cotton Seed Co., Newport, Ark.

Wilson Type Big Boll: Developed by Lee Wilson & Co., Wilson, Ark., from a strain of Piedmont Cleveland provided by H. W. M. Collins, plant breeder for the company.

Strains recently developed by private breeders in Texas:

Gorham Lone Star: 1906, Developed by John Gorham & Son, Waco, Tex., from Lone Star. Work was carried on continuously for 30 years, beginning with the original selection, which was grown on this farm the year after it was made by D. A. Saunders in 1905. Staple 31/32 to 1 1/32 inches, gin outturn 38 to 41 percent, bolls about 60 to the pound.

New Boykin and Ferguson Triumph 406: 1908, Developed by the Ferguson Seed Farms (formerly of Sherman, now of Howe, Tex.), from Mebane Triumph. Both early, small, low-branching plants; staple 7/8 to 1 inch, gin outturn 36 to 39 percent, bolls medium to large, storm-resistant. Widely distributed in northern Texas, Oklahoma, and Arkansas for a number of years. Somewhat more concentrated in Texas in recent years.

Buckelew Mebane: Introduced about 1912 by Buckelew Bros., Troy, Tex. Strain of Mebane Triumph.

Kasch: Introduced about 1912 by Ed Kasch, San Marcos, Tex. Strain of Mebane Triumph. Widely sold for a number of years.

Bennett Lone Star: Introduced about 1917 by R. L. Bennett & Sons, then located at Paris, Tex., now at San Antonio. (R. L. Bennett had formerly been with the United States Department of Agriculture and cooperated with the Texas Agricultural Experiment Station in cotton-breeding work.) Somewhat more uniform and slightly shorter jointed than the parental strain, but too late maturing to maintain popularity in the regions where the seed was usually

sold. About 1926, Bennett began to breed an earlier type of Lone Star; later he developed from new stocks a strain somewhat like Stoneville. Present stocks of the firm are reported to be represented by two strains, designated as Row 5 and Row 8.

Lankart: 1918. Variety developed from Lone Star by C. S. Lankart, Waco, Tex. First selection in 1911, thought to have been a natural hybrid. Spreading plant, drought-resistant; bolls very large, storm-resistant; gin outturn 38 to 41 percent; staple $^{31}/_{32}$ to $1\frac{1}{32}$ inches.

Bryant Mebane: About 1918. Strain of Mebane Triumph introduced by John J. Bryant, Corsicana, Tex. Compact plant, early bolls, large, picks well; gin outturn 38 to 41 percent, staple $^{15}/_{16}$ to 1 inch and hard-bodied.

Sunshine: About 1918. Strain of Rowden, introduced by the J. W. Davidson Co., McKinney, Tex. Earlier than parent, staple $^{15}/_{16}$ to $1\frac{1}{32}$ inches, gin outturn 34 to 37 percent, bolls 65 to 70 to the pound.

H-X: Introduced about 1920, by Kinsler-Hartman, Austwell, Tex. The parent of H-X was a strain of Lone Star introduced by this firm in 1916. Both have a gin outturn of 38 to 41 percent, bolls around 60 to the pound. H-X has a much shorter jointed plant than the Lone Star strain.

Russell (not to be confused with the Russell having green seeds developed in Georgia from Truitt): Introduced about 1920. Strain of Lone Star, introduced by the Russell Cotton Breeding Farms, Annona, Tex. Somewhat earlier than parent. Staple $^{15}/_{16}$ to $1\frac{1}{32}$ inches, gin outturn 36 to 38 percent, bolls about 70 to the pound.

Worley Boykin: About 1921. Strain of New Boykin, introduced by F. W. Worley, Rockdale, Tex.

Young Improved Acala: 1922. Acala 5 type, produced by W. T. Young, Acala, Tex. (died Apr. 8, 1935). Breeding work practiced and new strains of the type Y 23 and Number 9 introduced. W. Z. Ryan, breeder 1925 to 1935.

Harper: About 1922. Selection of Mebane Triumph, developed by Robert M. Harper, Martindale, Tex. Staple $^{15}/_{16}$ to 1 inch, gin outturn 38 to 41 percent, bolls about 70 to the pound. Continuously bred for about 15 years.

Paris Big Boll: About 1922. Stock of Bennett Lone Star, introduced by Farmers' Seed & Gin Co., Paris, Tex. Staple $^{31}/_{32}$ to $1\frac{1}{32}$ inches, gin outturn 38 to 41 percent, bolls around 60 to the pound.

Qualla: About 1922. Strain of Mebane Triumph, developed by H. Conrads, San Marcos, Tex. Staple $^{15}/_{16}$ to 1 inch, gin outturn 38 to 41 percent, bolls 70 to the pound. Widely distributed in Texas and adjoining States. Most popular recent variety in Texas outside of Kasch.

Hurley Special: 1923. Strain of Rowden, introduced by H. C. Hurley, Cooper, Tex. Breeding work begun in 1912. Somewhat earlier than parent, better gin outturn, more uniform staple, better quality of fiber.

Rogers Improved Acala: Introduced commercially about 1923 by John D. Rogers, Navasota, Tex. Breeding begun in 1921. Rogers strains have been multiplied and distributed by the Sartartia Plantation and the Sugarland Industries, Sugarland, Tex. Recently R. H. Goble & Co., ginners, Sherman, Tex., through their customers, have been growing Rogers Improved Acala and marketing the seed as State certified.

Cliett Superior: Introduced 1924 by the Cliett Cotton Breeding Farms, San Marcos, Tex. Developed from Mebane Triumph stocks obtained from A. D. Mebane in 1920, when the breeding work was begun. Better strains brought out subsequently under this trade name. Bred more especially for central and western Texas and western Oklahoma.

Hasselfield Lone Star: 1924. Produced by O'Connor-Hasselfield, Tivoli, Tex. Strain of Lone Star. Selection work begun in 1921 by B. V. Hasselfield. Stock kept up to present time by continuous selection. Strong short-jointed main stem, long fruiting branches, large bolls hanging downward, high lint percentage, lint of high quality.

Texas Special: 1925. Strain of Kasch, introduced by Stuffleheme Bros., Itasca, Tex. Staple $^{31}/_{32}$ to $1\frac{1}{32}$ inches, boll size and gin outturn similar to parent.

Chapman Ranch Mebane: 1926. Strain of Mebane Triumph, introduced by the Chapman Ranch, Chapman Ranch, Tex. Gin outturn 38 to 41 percent, bolls about 70 to the pound, staple $^{15}/_{16}$ to 1 inch.

Wacona: 1927. Variety developed from Lankart. First plant selected in 1921. Plant short, compact, and rigid. Somewhat earlier than Lankart. Bolls somewhat smaller (about 60 to the pound), round nose, storm-resistant, gin outturn 33 to 35 percent, lint $1\frac{1}{32}$ to $1\frac{1}{16}$ plus.

Aldridge A-1: Introduced about 1927 by the Aldridge Seed Farms, Plano, Tex. Strain of Kasch.

Texas Mammoth: Introduced about 1927 by the Von Roeder Seed Farms, Knapp, Tex. Strain of Mebane Triumph. Breeding work begun in 1923.

More vigorous and more open plant, bolls larger and bur heavier, staple longer than parental variety.

Saunders Special: Introduced about 1929 by the Saunders Seed Co., Greenville, Tex. Strain of Kasch.

Bagley Better Cotton: Introduced 1930 by W. W. Bagley & Sons, Martindale, Tex. Strain of Mebane Triumph. Breeding work began 1919. Large bolls, superior staple, productiveness are some of the objectives of the breeder.

Watson: Present strain introduced about 1932 by Ferris Watson, Garland, Tex. Developed from older lines of Mebane Triumph. Began breeding work in 1907 with stocks of seed from A. D. Mebane. Watson formerly bred and sold a strain of Acala 8 also.

Summary of Research in Cotton Breeding and Genetics at State Stations

Inheritance of Qualitative Characters

ARIZONA.—Determined: Red plant color, single factor difference from normal green. Yellow pollen color, single factor difference from normal cream. Slick seed, single factor difference from normal fuzz.

ARKANSAS.—Determined: Plant color and okra-leaf shape each single factor differences from normal. Three kinds of brown lint: Nankeen, Algerian brown, and Texas rust, each single factor differences from normal. Green lint, single factor difference from normal. Each of these characters is of the intermediate type of inheritance. Being studied: Petal spot, anther color, gland color. Linkages: Plant color, okra-leaf shape, and lint color (Nankeen or green) are inherited independently. No definite linkage studies being made. All characters so far are apparently independent.

FLORIDA (cotton work discontinued in 1933).—Determined: Monohybrids, dominant listed first: Naked seed versus fuzzy tip seed, fuzzy tip seed versus fuzzy seed, petal spot versus no petal spot, buff anther versus white anther, colored seed fuzz versus colorless fuzz. Incompletely dominant monohybrids: Okra leaf versus normal, red plant color versus green plant color.

LOUISIANA.—Being studied: Leaf shape, leaf form (round leaf), plant hairiness.

MISSISSIPPI.—Determined: Such characters as plant color, leaf shape, lint color, and seed coat which have been worked out before by other workers have been verified. Being studied: Attempting to determine whether any of the above characters are associated in any way with lint length.

NEW MEXICO.—Determined: Another color, yellow versus white. Two factors *P* and *B* responsible for color. Inhibitor *I* prevents action of *P* or *B* where one is present without the other.

NORTH CAROLINA.—Determined: Smooth (black) seed × fuzzy seed 3 : 1 ratio. Smooth seed × fuzzy tip seed 12 : 3 : 1 ratio. Fuzzy tip seed × fuzzy seed 3 : 1 ratio.

OKLAHOMA.—Determined: Plant color, red and yellow each by normal. Leaf shape, okra, and Egyptian each by normal. Lint, brown by normal. All 3 : 1 ratios, but not all cases definitely proved. Being studied: Further work on same characters.

TENNESSEE.—Being studied: Green, brown, and gray fuzz.

TEXAS.—Determined: Pollen color—3 dark yellow, 1 light yellow; 3 light yellow, 1 cream. Petal color—3 yellow, 1 cream. Petal spot—3 spot, 1 no spot. Lint color—3 brown, 1 white; 3 green, 1 white. Leaf shape—1 normal, 2 intermediate, 1 forked. Seed fuzziness—3 naked, 1 fuzzy (*G. hirsutum*). Leaf color—3 red, 1 green; 3 green, 1 virescent yellow; 3 bronze, 1 virescent yellow; 3 green, 1 yellow (lethal); 15 green, 1 yellow (lethal). Being studied: Short fruiting branch, withered lock, branched stamens, leaf color, leaf shape, lintless, lint color, cotyledon folding, petal color, petal spot, pollen color, chimaeras, fluted edge leaf, storm resistance, sunken boll.

Inheritance of Quantitative Characters

ARIZONA.—Determined: Lint length and seed size, each controlled by a number of factors. Being studied: Length of branches and size of bolls. Inheritance of fineness of fiber in hybrids. Correlations: Slick seed and low lint percentage. Fuzzy seed and high lint percentage. Extreme earliness and low yields. Long lint and low lint percentage. Extreme earliness and small bolls.

ARKANSAS.—Determined: Height of plant, number of nodes, length of staple, lint index, seed weight, lint percentage. Each of these characters apparently influenced by a number of factors. Sparse lint and abundant lint segregate

bimodally. Being studied: Oil and protein content and other seed and plant characters. Degrees of seed fuzziness, lint percentage. Fiber length, diameter, strength, uniformity, and color as measured by more refined methods. Correlations: Softness or silkiness of lint and green color. Sparse lint and clean or slick seeds.

LOUISIANA.—Correlations: Boll size and seed size.

MISSISSIPPI.—Being studied: Lint percentage and staple length. Correlations: The bare seed coat and green lint factors depress the expression of lint percentage.

NEW MEXICO.—Determined: None except in connection with correlation studies. Correlations: Lint index and lint percentage positive in four lines tested. Boll weight and lint index positive in two lines tested. Boll weight and total bolls positive in one line tested. Boll weight and loss in length positive in one line tested. Boll weight and total fibers positive in one line tested.

NORTH CAROLINA.—Determined: High lint percentage dominant to low percentage, several factor difference. Correlations: High degree between smooth seed and low lint percentage.

OKLAHOMA.—Determined: Sparse lint by normal lint, 25 percent sparse linted in F_2. Being studied: Lint percentage, lint length, amount of fuzz, cluster type of plant. Correlations: Possibly exists between color of lint and amount of fuzz and between lint percentage and amount of fuzz. Other correlations, see Oklahoma Experiment Station Bulletin 187.

TENNESSEE.—Being studied: Length and fineness of fiber. Cluster types and their relation to quality of lint. Correlations: Fiber length and fineness in relation to the fuzz colors are being studied.

TEXAS.—Determined: Length of lint—multiple factors; percentage of lint—multiple factors; shape of boll—varietal crosses, single factor; species crosses, multiple factors. Loculi number—varietal crosses, single factor; species crosses, multiple factors. Petal length—multiple factors. Stigma length—multiple factors. Being studied: Short petal, effect of leaf color on yield, length of lint, percentage of lint, shape of boll, stigma length, petal length, number of loculi. Correlations: Seed fuzziness and amount of lint, plant color and fruiting habit, petal color and number of loculi, pollen color and number of loculi, petal color and pollen color, lignin and palisade cells. Length and percentage of lint in F_2 of varietal and species crosses showed low negative correlation. Also see Texas Agricultural Experiment Station Bulletins 332, 354, 364, 369, and 452 for additional results.

Fiber Research

ARIZONA.—Study of effects of selection on uniformity of lint length indicates possibility of establishing strains with less substaple than exists in those ordinarily grown.

ARKANSAS.—Studies on the influence of environmental factors on 16 fiber and seed variables completed. Variety, location, and season identified as highly significant contributors to variation. Individualistic response of varieties and variables to environmental conditions was found. Metaxenia in fiber diameter has been established in certain crosses.

LOUISIANA.—Length and uniformity studies of prominent varieties of the State. (See Louisiana Experiment Station Bulletin 259.)

NEW MEXICO.—Fiber sorter used especially for determining percentage of 1⅛ inches plus fibers. Uniformity of length being stressed in present researches.

NORTH CAROLINA.—Studies of source and care of planting seed under farm conditions in relation to length of staple show that improved stocks are a very important factor in the production of uniform staple length. The value of pure seed stocks has been demonstrated in spinning tests. Fiber fineness has been isolated and this property is being evaluated in manufacturing tests. Results so far are very encouraging.

OKLAHOMA.—Length, strength, and uniformity studies as affected by disease, fertilizer, variety, time of picking, and self-pollination.

TENNESSEE.—Fiber graph studies are being made on position of hairs around seed, on different seeds in lock, on different locks in boll, and on different bolls. Five thousand six hundred bolls were cataloged for this study.

TEXAS.—Studies have been initiated to determine the inheritance of strength, length, diameter, and convolutions.

Methods for Inducing Mutations and Results

ARKANSAS.—One hundred seeds from each of the 8 pure genotypes of the trihybrid red plant, okra leaf, lint color combination were subjected to X-ray treatment, using a dosage of 12 milliamperes, 50 kilovolts, 18-cm target distance, and 30- and

60-minute exposures. No mutations were found in the plants developed from the treated seeds nor in the next generation.

CALIFORNIA (all Federal work).—X-rays used to limited extent; results so far very unsatisfactory.

LOUISIANA.—X-ray treatment given dry seed, soaked seed, and flower buds. Several stunted and abnormal forms were secured but nothing of economic value.

TENNESSEE.—Trying place effect. California Acala has been grown on a 5-acre area successfully for the past 6 years at Murfreesboro. The seed have been saved and planted the following year. No mutations have been observed as yet.

TEXAS.—Dry seed exposed to X-ray at dosages of 15, 30, 45, 60 minutes, 100 kilovolts, 5 milliamperes, and 17-cm target distance. Produced mutations, including progressive mutations in leaf color and shape which are transmitted to succeeding generations. Artificial induction of polyploidy by low and high temperatures is also being tried.

Cotton Degeneration Studies

MISSISSIPPI.—Cotton degeneration studies to determine in what ways and how rapidly varieties deteriorate and to determine what plant breeding methods would best maintain a strain or variety of cotton once it is bred to a high state of purity.

Plant Characters Emphasized as Objectives of Improvement in the Breeding Programs at State Stations

[Listed in each case in the order given by the workers reporting]

ALABAMA.—Early maturity, high yield, medium to large bolls, 15/16 to 1 1/16 inches staple, ease of picking, high gin outturn, disease resistance.

ARIZONA.—Upland—High yield, uniformity of lint length and plant type, high lint percentage, high lint index, large bolls, storm resistance, disease resistance, earliness.

ARIZONA (Federal work on American-Egyptian).—A productive, early-maturing, as nearly as possible limbless plant, with lint of relatively uniform length, fine, strong and abundant, and seeds as nearly smooth as possible.

ARKANSAS.—Early maturity, high yield, medium to large bolls, medium staple length for upland, longer staple for bottom land, generally good fiber quality, high lint percentage, wilt tolerance or resistance, storm resistance.

CALIFORNIA (all Federal work).—Strong upright stalk, indeterminate habit of growth, open type as distinguished from cluster, disease resistance.

GEORGIA.—High yield, a good quality of lint, wilt resistance.

LOUISIANA.—Better production, more uniform staple, larger bolls, longer staple in Dixie-Triumph selections.

MISSISSIPPI.—For upland, somewhat more vigorous and spreading plants, medium foliage, medium to big bolls. For Delta, light foliage, smaller plants, 1 1/8-inch to 1 3/16-inch staple. High yields in both sections.

NEW MEXICO.—Uniformity of staple length, seedling vigor.

NORTH CAROLINA.—Medium growth, light foliage, early maturity, large bolls, 1 1/16-inch staple, high spinning quality.

OKLAHOMA.—Earliness, large bolls, high lint percentage, inch lint length, uniformity, and high quality of fiber.

SOUTH CAROLINA (breeding work commercial entirely).—Yield, high lint percentage, satisfactory length of lint, strength and uniformity of lint, earliness of fruiting and maturity, size of boll, thickness and toughness of hull, disease resistance, storm resistance, ease of picking.

TENNESSEE.—Staple 1 to 1 1/16 inches, earliness, 35 to 45 percent of crop harvested first picking, yield comparable with Stoneville 2, size of boll not more than 80 to the pound, lint index around 7.5, lint percentage not below 35 percent, vigorous prolific spreading type of plant.

TEXAS.—High yield of tenderable staple, high lint percentage, large storm-resistant bolls, types adapted to mechanical harvesting.

Department of Agriculture

The Department of Agriculture through the Division of Cotton and Other Fiber Crops and Diseases of the Bureau of Plant Industry is cooperating in cotton breeding or genetics with all the State stations in the Cotton Belt that have a research program of this kind. Last year Department personnel were placed in North Carolina, South Carolina, Georgia, Tennessee, and Mississippi. In 1936 field men have been located at Alabama, Louisiana, Arkansas, Oklahoma, and Texas. For some years the Department has had field stations in Texas, New Mexico Arizona, and California. The Department has been carrying on

cytogenetic and toxonomic studies of cotton and some of its relatives in California and genetic studies in Egyptian and upland cotton in Arizona. In 1935 genetic studies in upland cotton were begun cooperatively in South Carolina and Mississippi. In 1936 cooperative work in genetic studies was begun with Arkansas and Texas. Breeding and improvement work has been carried on for a number of years at various points in the Cotton Belt. Cooperative breeding and improvement work was begun in 1935 with the stations of North Carolina, South Carolina, Georgia, and Tennessee, and in 1936 this cooperative arrangement in cotton breeding and improvement was extended to Oklahoma, Louisiana, and Alabama.

List of State Station and Federal Field Workers in Cotton Breeding and Genetics in the United States

[Asterisks denote: (*) Federal; (**) State and Federal]

State	Post office	Name of worker
Alabama	Auburn	H. B. Tisdale** (cotton breeding).
	do	J. B. Dick* (cotton breeding).
Arizona	Tucson	W. E. Bryan (cotton breeding).
	do	E. H. Pressley (cotton breeding).
	Sacaton	C. J. King* (cotton breeding).
	do	R. H. Peebles* (Egyptian cotton breeding and genetics).
	do	H. J. Fulton* (Egyptian cotton breeding and genetics).
Arkansas	Fayetteville	L. M. Humphrey (cotton breeding and genetics).
	do	Landis S. Bennett* (cotton genetics and breeding).
California	Riverside	J. M. Webber* (cotton genetics and cytology).
	Shafter	G. J. Harrison* (cotton breeding and genetics).
Georgia	Experiment	R. P. Bledsoe (cotton breeding).
	do	G. A. Hale (cotton breeding).
	do	W. W. Ballard* (cotton breeding).
	do	A. L. Smith* (cotton breeding in disease resistance).
Louisiana	Baton Rouge	H. B. Brown (cotton breeding and genetics).
	do	John R. Cotton* (cotton breeding and genetics).
Mississippi	State College	J. Fred O'Kelly (cotton breeding and genetics).
	Delta Branch Station, Stoneville.	W. E. Ayres (cotton breeding).
	do	H. A. York (cotton breeding).
	do	J. W. Neely* (cotton genetics and breeding).
New Mexico	State College	G. N. Stroman (cotton breeding and genetics)
	do	A. R. Leding* (cotton breeding).
North Carolina	Raleigh	J. H. Moore (cotton breeding in reference to fiber).
	do	P. H. Kime** (cotton breeding).
Oklahoma	Stillwater	L. L. Ligon* (cotton breeding and genetics).
South Carolina	Pee Dee Branch Station, Florence.	W. H. Jenkins* (cotton breeding and genetics).
Tennessee	Knoxville	Newman I. Hancock (cotton breeding).
	do	D. M. Simpson* (cotton breeding).
Texas	College Station	D. T. Killough (cotton breeding and genetics).
	do	G. T. McNess (cotton breeding).
	Substation No. 3, Angleton	R. H. Stansel (cotton breeding).
	Substation No. 1, Beeville	R. A. Hall (cotton breeding).
	Substation No. 12, Chillicothe.	J. R. Quinby (cotton breeding).
	Substation No. 6, Denton	P. B. Dunkle (cotton breeding).
	Substation No. 8, Lubbock	D. L. Jones (cotton breeding).
	Substation No. 11, Nacogdoches.	H. F. Morris (cotton breeding).
	College Station	T. R. Richmond* (cotton genetics and breeding).
	U. S. Field Station, Greenville.	H. C. McNamara* (cotton breeding).
	do	D. R. Hooton* (cotton breeding).

Improvement in Flax

By A. C. Dillman,[1] *Associate agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry*

AMONG the five chief textile fibers produced directly by nature—cotton, jute, linen, wool, and silk—linen has long held an honorable and useful place. Before the development of cotton textiles, clothing was mostly made of linen and wool, and the spinning and weaving of linen were common household arts. The fiber lends itself to the making of thread that is coarse, strong, and long-wearing, or almost as fine as the gossamer from a spider's web. In addition, the oil from the seed of the flax plant is used in vast quantities to make paints, and its peculiar toughness when oxidized is employed in the making of linoleum, oilcloth, patent leather, and other products. The residue from the pressed seed, linseed cake, is ground into meal to be fed to domestic animals. Thus flax performs an unusually wide range of services as animal food, on painted surfaces, on floors, and in the form of clothing, table linen, handkerchiefs, and other useful or decorative textiles. To be clothed in purple and fine linen was an ancient mark of aristocracy and the gleaming whiteness of linen was a symbol of purity. Those who ran for political office in early Rome wore white linen togas made from Egyptian flax. The Latin word for white was candidus. So office seekers were called candidates, that is to say, wearers of white linen; and they are so called to this day.

However, primitive man was more interested in his food supply than in his raiment, and it seems probable that wild flax was first gathered for its seeds as a source of food. Remains of flax plants—the species uncertain—have been found in the refuse of the Stone Age pile dwellings of Switzerland. Indeed, flaxseed, ground with grain or other seeds, is still used for food in Ethiopia, India, the Union of Soviet Socialist Republics, and in some other countries.

The art of making fine linen was practiced by the ancient Egyptians, which indicates that at a very early period flax was already a well-developed cultivated crop.

Vavilov (*29, p. 183*),[2] who has made an extensive botanical and geographical study of flax varieties obtained from every possible source,

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[1] The writer wishes to acknowledge the hearty cooperation of the agronomists of the several flaxseed-producing States and of foreign countries who furnished information in regard to flax improvement and superior varieties developed in the several States and countries. He is also indebted to J. C. Brinsmade, Jr., and B. B. Robinson for their cooperation and suggestions in the preparation of this article.

[2] Italic numbers in parentheses refer to literature cited, p. 772.

considers that "the oldest regions of cultivated flax are in Asia: India, Bokhara, Afghanistan, Khoresan, Turkestan; on the coasts of the Mediterranean: Egypt, Algeria, Tunis, Spain, Italy, Greece, Asia Minor." He is inclined to agree with De Candolle that flax may be of "polyphyletic origin"—that is, it developed from two or three species which united into the one species *Linum usitatissimum.*

Other investigators believe that the wild flax, *Linum angustifolium*, which is native to the whole Mediterranean region, may be the species from which cultivated flax originated. This is the only wild species that crosses readily with cultivated flax, and as Tine Tammes (*24*) points out in her extensive study of hydrids, "the investigation affords strong support for the hypothesis that of all wild *Linum* species, *L. angustifolium* can be considered as the most probable parent plant of *L. usitatissimum.*" Both species are annuals, or winter annuals in mild climates, and both have the same number of chromosomes, according to most investigators. *L. angustifolium* is a fine-stemmed plant, with two or several basal branches according to the thickness of planting, small deep-lavender flowers, dehiscent bolls (that is, bolls that burst when ripe), and small brown seeds. The species, as found in different localities, shows considerable variation in plant, flower, and seed characters, although much less variation than cultivated flax.

If one considers the great length of time that flax may have been grown by primitive peoples, it seems not impossible that the many types and varieties of cultivated flax may have evolved from this wild species.

The Distribution of Flax and the Outstanding Achievements in Breeding

THIS article deals chiefly with flax grown for seed, although the genetic factors of both seed and fiber flaxes are essentially the same. Seed flaxes are short to medium in height, 15 to 30 inches, whereas fiber flax is taller, 30 to 48 inches. The seeds of linseed varieties range in size from small to large, 2.5 to 11 grams per 1,000 seeds, whereas seeds of fiber flax are uniformly small, weighing from 3 to 5 grams per 1,000 seeds. The small stems of fiber flax, without basal branches, are produced chiefly by means of a heavy rate of seeding, 80 pounds or more to the acre. Flax for seed production is sown at the rate of 24 to 42 pounds to the acre. The greater length, fineness, strength, and yield of fiber in the fiber flaxes have been brought about by careful selection of superior types. A mild, humid climate is also of first importance in the production of high-quality flax fiber (fig.1).

Flax is grown commercially in 30 or more countries, and on all continents. The annual world production of flaxseed is about 120 million bushels, although in 1932 it reached 166 million bushels. Argentina is the principal seed-producing country; its production usually runs from 50 to 70 million bushels a year, but in the crop year 1931–32 it reached 89 million bushels. India produces from 15 to 20 million bushels annually. In Europe flax is grown chiefly for fiber, except in the Union of Soviet Socialist Republics, where both fiber

flax and seed flax are produced. Seed production during the period 1931 to 1935 exceeded 30 million bushels annually in the Union of Soviet Socialist Republics.

In North America flax is grown in the United States and Canada and to a limited extent in Mexico. Since 1908, the lowest production in the United States was about 5 million bushels in the dry season of 1934, and the highest was 31 million bushels in 1924. Normal production may be considered as from 10 to 22 million bushels a year.

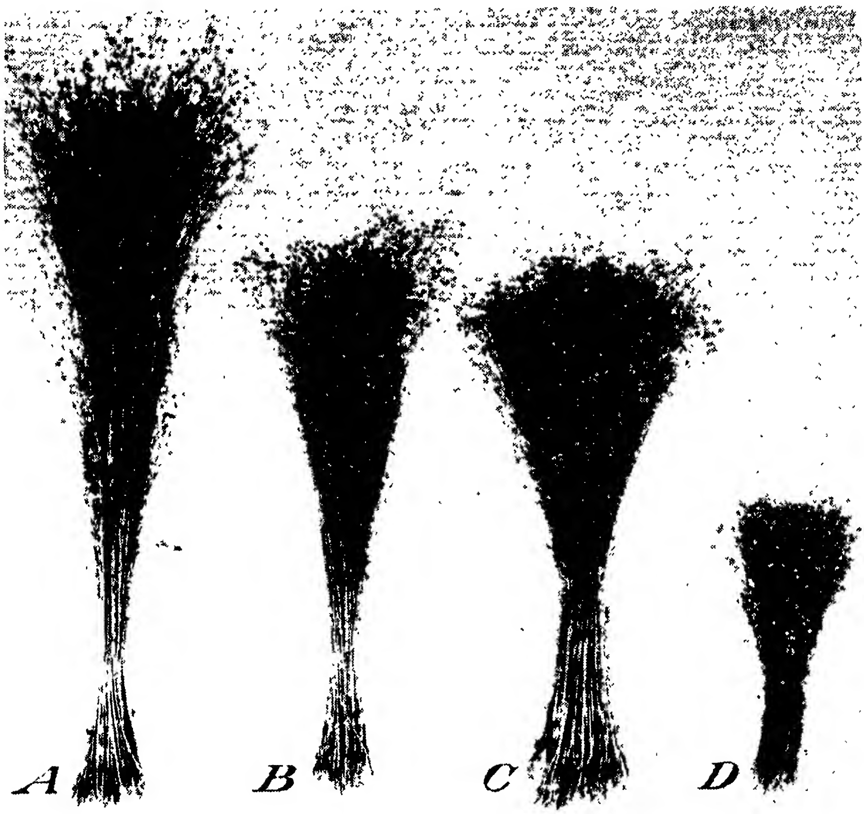

FIGURE 1.—Four varieties of flax showing range in height from 36 to 15 inches, as grown at St. Paul, Minn.: *A*, J. W. S.; *B*, Redwing; *C*, Bison; *D*, Indian. Indian flax, adapted to a long growing season, is 20 to 30 inches high when grown as a winter crop in the Imperial Valley, Calif.

Between 1911 and 1926, Canadian production of flaxseed ranged from 5 to 26 million bushels (in 1912), but since 1931 it has been less than 3 million bushels annually.

EARLY HISTORY IN THE UNITED STATES

The cultivation of flax for fiber was begun by the colonists in America soon after their settlements had become established. A bounty was offered by the assembly of Virginia in 1658 to persons who would produce flax fiber of a certain value, but apparently it was nearly a century later before the plant was grown in commercial quantity. The cultivation of flax was more extensive in New York, New Jersey,

and Pennsylvania than in the other Colonies, and by 1770 flaxseed was a staple article of export from New York.

The invention of the cotton gin in 1792, followed by the development of the cotton industry, checked the cultivation of flax for fiber. It was probably at about this time that the manufacture of linseed oil was begun in the United States, and by 1810 there were numerous small linseed mills in operation in Pennsylvania and New York. The linseed-oil industry developed rapidly during the half century from 1850 to 1900, and the cultivation of flax extended successively to new lands in Ohio, Indiana, Illinois, Iowa, Minnesota, and the Dakotas. According to the census of 1900, North Dakota, Minnesota, and South Dakota produced 16,110,000 bushels of flaxseed in

THE story of flax improvement centers primarily about the successful battle against diseases that threatened to wipe out the industry completely . . . In 1900 H. L. Bolley of North Dakota determined that flax wilt was caused by a parasitic fungus, which he segregated, described, and named. Bolley's work is classical. He was probably the first man in the history of agriculture to submit plants to an epidemic of disease in order to obtain selections resistant to the disease. This method makes deliberate use of the principle of the survival of the fittest. Today it is basic in all crop improvement . . . Bolley's work completely altered the outlook for flax production in this country.

1899. These three States still produce about 90 percent of the total United States crop.

Just what type of flax was grown during the colonial period is not known definitely, but it probably was a short-fiber plant—that is, one of medium height with blue flowers and small brown seeds. It is likely that this same type was grown in the Middle West (Ohio to Iowa), for it was not until about 1890 that the larger-seeded oil flax, known as "Russian flax," was brought to North Dakota from the Ukraine and southern Russia. It should be noted, however, that flaxseed for crushing was imported from Russia and from India before 1850, the first cargo coming from Russia in 1839. The importation of Indian flaxseed has been carried on almost continuously since that time, but Indian flax, of the short type, is not well adapted to our northern climate, and it has never been grown commercially in the North Central States.

In 1890 the United States Department of Agriculture (7) began extensive experiments to revive the fiber flax industry, which had almost entirely disappeared in this country. Seed of fiber flaxes from Russia, the Netherlands, Ireland, and other countries was introduced and sown in extensive trials in 20 or more States, extending from New York to California and from Missouri to North Dakota. Fiber of fair quality was produced in Michigan, Minnesota, and Oregon, but no new flax industry resulted from these tests. The fiber-flax industry in Michigan was developed chiefly by James Livingston about 1880, and fiber flax continued to be grown in that State for commercial spinning until 1920. Since 1920 it has been grown chiefly for upholstery tow.

HOW BREEDERS CONQUERED THE DEADLY FLAX WILT

The story of flax improvement centers primarily about the successful battle against diseases that threatened to wipe out the industry completely. Recently, breeding plants for high oil content, combined with better drying quality in the oil, has received major attention in the flax-producing States.

The earliest improvement work in the United States was carried on in Minnesota and in North Dakota, and the most extensive work is still carried on there. As far back as 1890, Lugger (*15*), in Minnesota, conducted experiments to determine the effect of soil fertilizers and of seed treatment by fungicides on the control of flax wilt, and of flax straw as a source of infection. In 1896 Snyder (*21*) published the results of his studies on the fertilizer requirements of the flax crop. He proved that the lack of soil fertility was not the cause of the failure of the crop.

At about this time W. M. Hays, at the Minnesota Agricultural Experiment Station, began the selection of flax by the "centgener method," that is, by comparing the progeny of selected individual plants grown in squares of 100 plants each. By this method Primost (Minnesota No. 25) was developed from a single plant selected in 1894, and distributed by Hays from 1900 to1904. So far as is known to the writer, this was the first pure-line variety produced in the United States.

It was in 1900 that H. L. Bolley (fig. 2) of North Dakota determined that flax wilt was caused by a parasitic fungus, *Fusarium lini*, which he described and named in 1901 (*3*). Unknown to Bolley, an earlier report on the disease had been published in 1896 by N. Hiratsuka in Japan. This author reported that the wilt was caused by a *Fusarium* fungus.

Bolley's work is classical in the field of flax improvement. He and Orton, working independently with different crops, probably were the first men in the history of agriculture to submit plants to an epidemic of a disease in order to obtain resistant selections. Somewhat earlier, in 1899, W. A. Orton, of the United States Department of Agriculture, had made plant selections that were highly resistant to the cotton wilt disease, which had appeared in South Carolina. The notable results in the selection of wilt-resistant cotton were brought to the attention of Bolley and his associates in North Dakota as a possible method of developing a wilt-resistant flax. This method makes deliberate use of the principle of the survival of the fittest. Today it is basic in all crop-improvement work. Since those early days in

1900, Bolley has planted hundreds of lots of flaxseed, obtained from many sources, on wilt-infested soil, and has saved the few surviving plants as the parent stocks of the wilt-resistant varieties he has developed.

To understand the importance of this achievement, it is necessary to realize that it completely altered the outlook for flax production in this country. The older varieties, susceptible to wilt, could survive only on new land. Thus it was impossible to grow flax continuously on the same land, or even to grow it at intervals with several years between. With this handicap, flax production probably could not have survived. Bolley's contribution—begun before the days of modern genetics—consisted in letting a piece of land get thoroughly "flaxsick," heavily infested with the wilt fungus. Flax planted there just naturally lay down and died in its early youth. Yet an occasional plant would come through. That plant, Bolley knew, had something in its inheritance that enabled it to resist this blight. Patiently he bred and increased these lone survivors. Bolley's piece of ground has now been infested with wilt for some 40 years. Nothing has ever been done to reduce or combat the fungus. Ordinary flax planted in this soil cannot possibly survive. Yet today the plot produces as fine flax plants as anyone would want to see. They are highly resistant strains, proved and tested by generations spent continuously on the firing line.

FIGURE 2.—H. L. Bolley, botanist and plant pathologist, North Dakota Agricultural Experiment Station, Fargo, N. Dak., who, in 1900, discovered the organism, *Fusarium lini*, which causes flax wilt, and who selected the wilt-resistant varieties N. D. R. 114, Buda, and Bison, which have saved the flax crop for the North Central States.

The Story of Plot 30

Plot 30 at the North Dakota Agricultural Experiment Station, where Bolley and his associates did this work, is perhaps as important in human affairs as any historic battlefield. Its function, however, has been the saving, not the destruction, of man's resources. It is worth while to record the early history of this now famous plot of soil. The first sowing of flax on the plot was made in 1894 by J. H. Shepperd, now president of the North Dakota Agricultural College. Shepperd had seen the experiments of Lugger in the greenhouse at the Minnesota Agricultural Experiment Station during the winter of 1890–91 and was impressed by the striking results of these tests. The experiment consisted of three small plots or beds of flax sown on clean virgin soil. Bed 1 was a control and given no treatment.

Bed 2 was watered with an infusion obtained by soaking flax straw from a wilt-infected field in warm water. In this bed the flax plants were wilting or dead. Bed 3 was watered with the same infusion as bed 2 but the infusion had been boiled. In this bed the flax was green as in bed 1, the control. Dr. Lugger confessed that he did not know what he had except that "it evidently was 'alive.'" This demonstration stayed in Shepperd's mind and in 1893 when he came to North Dakota as agriculturist for the experiment station, he conceived the idea of growing a plot of flax continuously, year after year, "until something happens." Shepperd talked the matter over with Bolley, botanist, and Ladd, chemist, and told them what he had in mind approaching this flax problem. In 1900, after several years of cropping, the flax crop had failed on this continuously cropped plot. Professor Ladd made an analysis of the soil and reported that the fertility of the soil apparently had not diminished. At this time, the plot was turned over to Professor Bolley for his now famous flax-wilt

> "PLOT 30" *at the North Dakota Agricultural Experiment Station, where Bolley and his associates did their work on disease resistance, is perhaps as important in human affairs as any historic battlefield. Its function, however, has been the saving, not the destruction, of man's resources.*

investigations. In his first publication on flax wilt Bolley (*3, p. 36*) gives the following account of his early investigations:

> That we have been able to accomplish this so definitely is not due to an accidental or lucky find of a parasite. When I first met Dr. Lugger in the fall of 1890, he called my attention to the fact that "Flax is subject to the attack of a strange disease which has appeared in some counties of Minnesota." Since that date I have made each year some observations in flax fields, and have collected some specimens, attempting to ascertain a direct cause. Many microscopic sections were, from time to time, made and studied, but were negative in result until pure cultures, made during the summer of 1900, defined the organism to be looked for. Many previous attempts to obtain pure cultures had failed because of difficulties which were found hard to overcome, even when an abundance of diseased plants and soil was close at hand. This condition was made possible through the kind cooperation of Prof. J. H. Shepperd, the Agriculturist of this station. In the summer of 1893, Professor Shepperd agreed to crop one of his regular one-eighth acre rotation plots continuously to flax until something should happen. This something came markedly to notice July 1st, 1900, when all of the young plants on the flax plot were found to be dead or rapidly wilting. The records for this plot show that in spite of improved drainage and cultural methods, which had sufficed to raise the standard of all other crops upon the adjacent plots, the yield of flax was less each year after 1895. In 1899 it dropped from 12.3 bushels, the yield of 1898, to 7.4 bushels. In 1900 all plants were dead by the Fourth of July. At this time Professor Shepperd turned the plot over to the Botanical Department for investigation. I have since been unable to get any flax plants to reach maturity upon the soil of this plot. Indeed, most plants succumb before reaching a height of three inches. This plot is known in the College records as Rotation plot No. 30.

Subsequently, as already noted, it did prove possible to make flax grow on this deadly area.

Selection for disease resistance began soon after 1900 when Bolley determined the cause of flax wilt. Wilt-resistant varieties have been developed by Stakman (*22*) and his coworkers at the Minnesota Agricultural Experiment Station and by Bolley and his coworkers at the North Dakota station. Older varieties have been replaced as better ones came along.

At the present time Bison, developed by Bolley and Heggeness at the North Dakota station, is the leading commercial seed-flax variety in the United States. Although no official statistics are available, it is probable that 85 percent or more of the flax grown in Minnesota, the Dakotas, and Montana, the principal flax-producing area, is of the Bison variety. In a survey of flax fields made by the writer in late July 1934, he found 95 percent of the fields examined in the Red River Valley of North Dakota and Minnesota were planted to Bison. In southern Minnesota it was estimated that the acreage was divided between Bison (42 percent), Redwing (33 percent), and Buda (25 percent).

The application of the principles of genetics gave a new impetus to the breeding of improved wilt-resistant varieties of flax. Crossing of wilt-resistant varieties with those that were more productive has made it possible to produce new varieties combining wilt resistance with greater yield, higher oil content, and other desirable qualities. The application of this method, however, indicated that inheritance of wilt resistance and high productive qualities was more complicated than inheritance of many other characters which conform to a simple Mendelian interpretation. The problem was further complicated by the influence of environmental factors. Varieties that appeared resistant under some conditions wilted badly under others.

Wilt-resistant Varieties

In the "flax-sick soil" nursery at the Northern Great Plains Field Station, Mandan, N. Dak., where flax has been grown every year since 1914, considerable wilt occurs each year in all commercial varieties. The Bison variety, which is used as a check, is practically wilt-free at moderate temperatures, but wilts somewhat at high summer temperatures. Several promising new strains of hybrid origin, grown under the same conditions, remain entirely wilt-free throughout the season.

Bison, Linota, Redwing, Walsh, and Rio are fairly constant year after year for different degrees of wilt resistance. The Buda variety, which often has a moderate percentage of wilted plants, contains some strains that are practically wilt-immune. A Buda selection, C. I. 737, is one of these. This variety, used in crosses with susceptible varieties, has been a valuable parent in the transmission of wilt resistance.

Some further notes on disease resistance will be given later in the section dealing with genetic research. Meanwhile, it may be said that the following conclusions can be drawn from published results and the experience of breeders:

Investigation of wilt resistance in flax is a difficult problem, complicated (1) by environmental conditions of soil and temperature; (2) by differences in

the inherent capacity of varieties to resist the disease; and (3) by the virulence of different forms of the wilt organism.

Wilt resistance is inherited and may be combined with desirable agronomic qualities in crosses between resistant varieties and varieties that are superior in other characters except wilt resistance.

The high wilt resistance of flax varieties already developed is sufficient to insure profitable flaxseed production on wilt-infected soil under the climatic conditions of the principal flax-producing area of the United States.

The story of flax improvement in the United States would not be complete without reference to the excellent cooperation of the linseed-crushing industry with the flax-improvement program of the several States. The linseed crushers realized that their industry was entirely dependent on the success of the flax crop in the Middle Northwest, where it had made its last stand. It was with the cooperation of the flaxseed crushers and the paint manufacturers that Bolley was encouraged to carry on his notable work in the breeding of wilt-resistant flax. It has often been said that this fundamental work "saved the flax crop in the United States." Perhaps the leading genius of the linseed industry in this rescue job was the late C. T. Nolan (fig. 3), many years secretary of the flax development committee, representing the linseed and paint industries. Nolan supplied flax breeders with numerous commercial samples of flaxseed from foreign countries and was a world authority on the commerce of the crop and its industrial uses.

FIGURE 3.—C. T. Nolan (1871–1929) who for many years (1914–29) was chairman of the flax development committee representing the linseed-crushing and paint and varnish industries that gave valuable assistance to the improvement of the flax crop in the Middle Northwest.

Methods in Flax Breeding, and the Coming Problem of Breeding for Oil Content

HERETOFORE, improvement in flax has been based largely on yield and on disease resistance, especially resistance to wilt. With these qualities fairly well established in the varieties now grown, the next problem is to improve the yield and the drying quality of the oil. These are factors of prime importance to the linseed crusher and the user of linseed oil, and they must have a large part in any further breeding program.

The two principal markets for flaxseed in the United States are Minneapolis and Duluth, Minn., where the bulk of the flax grown in Minnesota, the Dakotas, and Montana is marketed. These markets receive fully 80 percent of the total United States crop. For 40 years or more Minnesota State grades for flaxseed have been in use at these markets. On July 1, 1934, the United States Department of Agriculture established Federal standards for flaxseed, which are essentially the same as the Minnesota grades formerly in use. The United States standards for flaxseed provide for two numerical grades and one sample grade (*28*).[3]

Flaxseed is purchased primarily for the oil it contains, which represents from two-thirds to three-fourths of the value of the manufactured products. Linseed cake or meal represents one-third or less of the value. It is well known that the oil content of different lots of flaxseed may range from as low as 33 to as high as 42 percent, based on dry weight. The bulk of the receipts on the Minneapolis market, however, range in oil content from 35 to 39 percent. Although the present official standards for flaxseed are commercially useful as measures of "condition," moisture content, and dockage in this product, they do not fully measure the processing value of flaxseed, which is governed principally by the oil content.

A difference of 4 percent in oil content between two lots of flaxseed means a difference of 2.24 pounds of oil per bushel of seed, or 3,360 pounds of oil in a carload of 1,500 bushels. Of course when there is more oil there is less meal. With oil at 9½ cents per pound and linseed meal at 1½ cents per pound—the approximate prices in October 1935—there is a net difference of nearly 18 cents per bushel in the value of the resulting products from the two lots of flaxseed. Therefore the carload of flaxseed with 4 percent higher oil content is worth $270 more than the car with the lower oil content.

Such differences in oil content and market value should be indicated on inspection certificates. Under the present grades for flaxseed, over 90 percent of the receipts at the principal markets grade no. 1, although different carlots within this grade often range from 34 to 40 percent in oil content. The Bureau of Agricultural Economics, United States Department of Agriculture, is now investigating methods of oil determination for the purpose of recommending a test that is practical for commercial purposes. This work is being done in cooperation with the agricultural experiment stations of the several flax-producing States and with the linseed industry.

Official inspection of flaxseed that would include a test for oil content would be an incentive to farmers to produce flaxseed of high quality, and would create a demand for new and better varieties of flax. It is now known that the yield and quality of oil is dependent partly on the weather conditions which prevail in any locality during the growing season—especially on soil-moisture supply, temperature, and length of the growing season—and partly on the variety of flax grown, that is, on inherited factors.

[3] No. 1 flaxseed requires a minimum test weight of 49 pounds per bushel, and may not contain more than 20 percent of damaged flaxseed. No. 2 flaxseed requires a minimum test weight of 47 pounds per bushel and may not contain more than 30 percent of damaged flaxseed. Sample grade includes flaxseed which does not come within the requirements of grades Nos. 1 and 2, or which contains more than 11 percent of moisture, or which is musty, sour, heating, or hot; or which is otherwise of distinctly low quality. In grading flaxseed, the test weight, moisture content, and percentage of damaged kernels of flaxseed are determined after the removal of dockage. Dockage includes weed seeds, cereal grains, stems, and all matter other than flaxseed, and also undeveloped, shriveled, and small pieces of flaxseed removed with the dockage and which cannot be recovered by properly rescreening or recleaning. The quantity of dockage is based on the weight of the flaxseed, including the dockage. The percentage of dockage, in terms of whole percentage, is added to the grade designation.

So far, the principal means of flax improvement in the United States has been by introduction from foreign countries, followed by selection of pure-line or single-line strains. Commercial and locally grown varieties also have been the source of new varieties developed by selection on the basis of yield and desirable agronomic characters, or on the basis of disease resistance. Flax may be considered a self-fertilized plant, although natural crossing may occur to the extent of 1 or 2 or even 5 percent in certain varieties. It is easy, however, to obtain comparatively pure strains by selection. It is noteworthy that Bison flax, obtained by plant selection in 1917, is still a very pure variety, which indicates continuous self-fertilization.

In connection with breeding work, the flax project of the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States

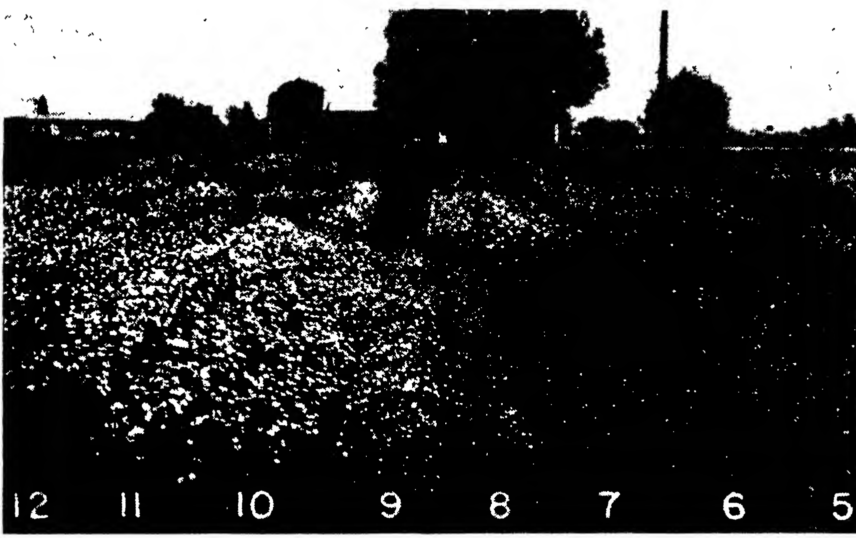

FIGURE 4.—Flax classification nursery showing in row 5 early-maturing dehiscent flax (C. I. 295); rows 6 to 9, short-branched Abyssinian flaxes; row 10, Roman Winter; and rows 11 and 12, seed flaxes of Argentine type. (Photographed at Bozeman, Mont., July 16, 1931.)

Department of Agriculture, has obtained a collection of over 900 samples of flaxseed. These have come from all the flax-growing countries of the world. The collection includes 124 varieties and pure-line strains obtained from Mrs. Howard (*11*) of India; 157 geographical varieties and strains from N. I. Vavilov of the Union of Soviet Socialist Republics; 16 pure-line strains of distinct flower and seed types obtained from Tine Tammes of the Netherlands; 80 or more lots of Argentine flax; 50 samples from Ethiopia, Egypt, Cyprus, Crete, and the Mediterranean area; and 20 or more from China and Japan. A large number of strains and varieties also have been obtained from Canada and from the several flax-producing States of the United States. A botanical classification of the many types and varieties of flax has been undertaken by the writer, but for the purpose

of this article the better known varieties may be included in a few more or less natural groups (fig. 4), which are given in the appendix (p. 773).

No varieties of flax of commercial importance in the United States have been developed by private breeders. Selection for disease resistance, yield and quality of oil, and yield and quality of fiber in fiber flax, involve rather technical tests for comparing varieties, and such facilities are available only at State and Federal experiment stations. Flax-breeding nurseries for testing varieties on wilt-infected soil are maintained at three stations—Fargo and Mandan, N. Dak., and St. Paul, Minn. Extensive work in breeding for wilt resistance is carried on at all three stations. Selection for rust immunity also requires controlled conditions, or maintenance of an epidemic of the disease. The Minnesota station makes extensive tests for rust resistance at Coon Creek, near Anoka, Minn., where the moist peat soil is exceptionally favorable for the development of a rust epidemic. A more certain test of rust resistance may be made by artificial inoculation under controlled conditions in the greenhouse, and such tests are a regular feature of the flax-breeding programs at both the Minnesota and the North Dakota stations.

In all practical breeding work it is important to keep in mind the qualities of disease resistance, high yield, early maturity, and the percentage yield and drying quality of the oil in seed flax, or the yield and spinning quality of fiber in fiber flax. All of these are varietal characters which it should be possible to combine, within certain limits, by hybridization and selection in the development of new strains or varieties. As resistance to wilt and immunity to rust are of prime importance, it would be impracticable, in breeding new varieties, to stop short of the degree of perfection already reached in the present commercial varieties. Several varieties, of quite diverse types, are immune to rust, a few are highly wilt-resistant, and still others have desirable seed and agronomic characters.

The following paragraphs will discuss varieties of flax developed in the United States by the three methods of introduction, selection, and hybridization. These varieties are listed in table 3 (p. 775) and their superior characters, their parentage, the methods used in development, the individuals responsible for the work, the year selected and distributed, and the estimated acreage in the United States are given. The agronomic and botanical characters of 22 outstanding varieties useful for present and future breeding work are given in table 4.

The work that has been done and is being done in flax breeding in the United States, with the names of the workers and their official connections is summed up on pages 779–784 of the appendix. The breeding work in foreign countries, insofar as this can be done on the basis of replies to the questionnaire on superior germ plasm in flax, or other available information, is also given. By consulting this part of the appendix the reader will get a general picture of what is being done abroad, with the names of the workers and institutions involved.

Improved Flax Varieties Introduced or Developed in the United States

INTRODUCTIONS

SEED of fiber flax from Russia, Belgium, and the Netherlands was introduced and grown in several States as early as 1891. Other importations of Russian seed—called Riga flax, from the city of export—have been made from time to time. The early fiber industry in Michigan was based on commercial seed obtained from Riga. The variety J. W. S. was introduced from Ireland in 1924. In recent years it has been the principal commercial variety of fiber flax in the United States (fig. 5). According to Searle (*19*) this variety was selected by J. Vargos Eyre during the period 1911–15. Some time later it was distributed as "J. W. S." in honor of John W. Stewart, a pioneer in the improvement of flax culture in Ireland.

In 1932, 12 selected varieties of fiber flax, C. I.[4] nos. 723 to 734, inclusive, were obtained from the Ministry of Agriculture for Northern Ireland. Liral 9 (C. I. 730) and Cirrus (C. I. 727) have produced a high quality of fiber in Oregon, where they are grown commercially to some extent.

The so-called Russian or common seed flax probably was brought to North Dakota by the German-Russian immigrants of that State before 1890. The lots of flaxseed (S. P. I.[5] nos. 9897–10381) introduced by H. L. Bolley in 1903, and later introductions by the United States Department of Agriculture, have been grown chiefly for the purpose of selection.

SELECTION

The important seed-flax varieties grown in the United States have been developed by single-line selection—that is, the increase of a single selected plant. As already noted, Primost was developed by W. M. Hays at the Minnesota Agricultural Experiment Station. It was selected in 1894 as a blue-flowered plant, probably a natural hybrid, from White Dutch, S. P. I. 10006. The wilt-resistant varieties developed by H. L. Bolley were single-line selections. North Dakota Resistant No. 114 was selected in 1902 from "common" flax grown in North Dakota. Buda was selected in 1906 from S. P. I. 10016, the original seed having been obtained by Bolley from a peasant farmer near Budapest, Hungary. It was reselected for several generations, 1908 to 1912, and finally increased and distributed in 1921.

Bison flax was selected by H. L. Bolley and his assistant O. A. Heggeness from commercial seed obtained from Belgium in 1911. Several selections were made by Bolley and grown from 1911 to 1917. In 1922 Heggeness planted seed from a bundle of plants, selection no. 243, grown by Bolley in 1917. This proved to be a highly wilt-

[4] C. I. indicates accession number of the Division of Cereal Crops and Diseases, formerly Office of Cereal Investigations.
[5] S. P. I. refers to accession number of the Division of Plant Exploration and Introduction.

resistant pure-line selection, the plants having distinctive deep-blue flowers and medium-large brown seeds. Apparently the selection was not grown from 1918 to 1921 and one wonders how near it came to being lost in the discard of surplus nursery material. Bison flax is now the principal commercial variety in the United States. The production in 1935 probably was over 10,000,000 bushels, having a market value in excess of $15,000,000.

Charles H. Clark, in charge of seed-flax investigations, Division of Cereal Crops and Diseases, United States Department of Agriculture, from 1913 to 1920, made numerous individual plant selections at the Northern Great Plains Field Station, Mandan, N. Dak. From these selections three commercial varieties have been developed. The variety Newland was selected from Reserve in 1914 (fig. 6). It was grown for several years at the Judith Basin Field Station, Moccasin, Mont., and on the basis of superior yield was distributed by the

FIGURE 5.—A 20-acre field of J. W. S. fiber flax near Dayton, Oreg., pulled by a flax pulling machine. The yield was 3½ tons an acre. (Photographed July 14, 1924, by B. B. Robinson.)

Montana Agricultural Experiment Station in 1926. Newland is drought resistant and immune to rust, but susceptible to wilt.

Punjab (C. I. 20) was selected by Clark from S. P. I. 36565, obtained in 1913 from William Burnes, economic botanist for India. Clark made several selections in 1914 and reselected in 1915. One of the taller selections (20–1–1) was retained under the designation Punjab, C. I. 20. Abyssinian (C. I. 36) was selected by Clark in 1914 and 1915 from S. P. I. 37086, obtained through the British legation from Soddo, near Addis Ababa, Ethiopia. This variety has the unusual combination of blue flowers and yellow seeds. The small yellow seeds yield an oil of superior drying quality.

The varieties Punjab and Abyssinian were included in a group of 10 varieties which the writer sent to L. G. Goar, superintendent of the Imperial Valley Experiment Farm, El Centro, Calif., in November 1927. Punjab proved to be one of the highest-yielding

varieties in the group, and it was increased and distributed to farmers in the Imperial Valley for growing in 1931. In 1935 about 40,000 acres were grown in the States of California and Arizona.

Redwing was developed by selection from S. P. I. 10006 at the Minnesota Agricultural Experiment Station. Selections were made by Stakman, Hayes, and Barker from 1914 to 1916 and seed was distributed to farmers in 1924. In 1925 reselections of individual plants were made by A. C. Arny to purify the variety for flower color. These single lines were tested for yield and wilt-resistance. What appeared to be the best selection was increased and distributed to farmers in 1930. Redwing is an early maturing variety which yields an oil of good drying quality.

Linota was developed by T. E. Stoa at the North Dakota Agricultural Experiment Station in cooperation with the United States Department of Agriculture. It was selected in 1916 from Frontier

FIGURE 6.—The early maturing Redwing flax (left) and Newland, a midseason variety, grown under irrigation at Bozeman, Mont., where yields of over 40 bushels an acre were obtained.

(N. D. No. 155) and first distributed to farmers in 1925. It was increased rapidly and it is probable that as much as 400,000 acres were grown in 1929. It is still grown to some extent in Kansas. Linota is moderately wilt resistant and its small seeds yield an oil of good drying quality.

HYBRIDIZATION

In recent years hybridization of flax varieties has been practiced by flax breeders at the State and Federal experiment stations in order to combine the superior qualities of different varieties. As early as 1914, Charles H. Clark, of the United States Department of Agriculture, made crosses of distinct varieties to study the inheritance of seed and flower characters, and to obtain new wilt-resistant lines. Since 1918 J. C. Brinsmade, Jr., in cooperation with the writer, has conducted the breeding work begun by Clark at the Northern Great Plains Field Station, Mandan, N. Dak. Recently Mr. Brinsmade

has developed several wilt- and rust-resistant strains from crosses of Bison and Buda with Argentine selections, and with Newland. His selections, made under conditions of limited rainfall, are more or less drought-resistant. Similar work was done from 1915 to 1920 by H. D. Long and H. L. Bolley at the North Dakota Agricultural Experiment Station, Fargo, N. Dak.

Henry (*10*) at the Minnesota Agricultural Experiment Station made crosses of Saginaw, Winona, and Chippewa with the rust-immune varieties, Argentine and Ottawa 770B. From these crosses, 35 rust-immune and wilt-resistant strains (C. I. nos. 651 to 687, inclusive) were obtained. None of them, however, has been superior to the Bison variety in wilt resistance or in yield of seed, and therefore they have not been increased or distributed in Minnesota. However, one selection, C. I. 677, Saginaw × Ottawa 770B, which combines a fair yield of fiber with good seed production, has been increased by H. B. Sprague for trial in New Jersey.

More recently, A. C. Arny, agronomist at the Minnesota station, has made crosses of Bison with Ottawa 770B, and with two smaller-seeded varieties, C. I. 391 and C. I. 423, with the object of improving the drying quality (iodine number) of the oil, which is inferior in the Bison variety. C. C. Allison, of the division of plant pathology and botany, University of Minnesota, has investigated the inheritance of wilt resistance and rust resistance in crosses of Bison with Argentine, Redwing, Ottawa 770B, and others. All of the flax-breeding work at the Minnesota Agricultural Experiment Station is conducted in close cooperation between the division of agronomy and plant genetics and the division of plant pathology and botany.

At the North Dakota Agricultural Experiment Station, H. L. Bolley and O. A. Heggeness have under way an extensive series of crosses of Bison with selections of Argentine, Buda, Golden, and others, with the object of improving the yield and quality of oil and still maintaining the wilt resistance of the Bison variety. L. R. Waldron is working on the same problem. All of the flax-improvement work at the North Dakota station is done in cooperation with T. H. Hopper, agricultural chemist, who is responsible for the chemical analyses.

VARIETIES RECOMMENDED FOR GROWING

A list of varieties of flax recommended by the experiment stations for growing in the United States (1936) is given below:

Minnesota: Bison, Redwing, Buda.
North Dakota: Bison, Buda, Linota.
South Dakota: Buda, Bison, Linota, Redwing.
Montana: Bison, Redwing, Newland (on wilt-free soil).
Kansas: Linota, Bison.
Iowa: Redwing, Bison (for very early seeding).
California: Punjab (C. I. 20), Abyssinian Yellow-seed (C. I. 36) (Argentine, C. I. 463 for trial).
Oregon:
Seed flax—Bison, Redwing, Newland (on wilt-free soil).
Fiber flax—J. W. S., Cirrus.

Fruitful Results of Genetic Research with the Flax Plant

ALTHOUGH heretofore most of the improvement in flax has been accomplished by single-line selection—the effective method of the practical plant breeder—there is a definite limit to the progress possible by this method, and in recent years flax breeders have made greater strides by applying the principles of genetics to their practical problems.

Although fiber flax and seed flax—linseed—are quite distinct crops from the standpoint of agriculture and industry, from the standpoint of genetics they are simply varieties of one species, and therefore they are considered together in this discussion. In a way, fiber flax is the elite member of the flax family. Its varieties are refined, tall, slender; they must maintain a certain quality or lose caste. Fiber flax is selected for the special purpose of producing the greatest possible quantity of strong fiber, fine and soft of texture, and of good spinning quality. The yield of seed is of secondary importance. In seed flax, on the other hand, the acre yield of seed of high oil content is of first importance, and there are numerous types and varieties of short, medium, or tall habit adapted to a wide range of climatic conditions. As in wheat, some varieties are adapted to a long growing season and may be fall-sown in mild climates, while others are adapted to the shorter growing season of the North.

The most extensive investigations of the genetics of flax have been made by Tammes (*25*) (fig. 7), of the University of Groningen, Netherlands, whose study of the inheritance of flower and seed color is classical. Her careful researches and her clear writing (she writes in three languages) have been an inspiration to flax breeders the world over and have served as a pattern for work in other countries. In India, similar work on flower and seed color has been done by Graham and Roy (*9*) and by Shaw and his coworkers (*20*). In the United States, the principal genetic researches have been on the inheritance of disease resistance and the yield and quality of oil in seed flax.

The inheritance of the several genetic characters in flax will be treated briefly here, as the excellent papers by Tammes, Shaw, and others are available to flax breeders.

CHARACTERS OF THE FLOWER AND BOLL

What color is the flax flower? Blue. And the seeds? Brown. True of most varieties. But there are also white-, pink-, and violet-flowered varieties, which have brown, yellow, greenish-yellow, chamois, mottled, or blackish-brown seeds. Moreover, the blue-flowered forms range in tone from deep blue to pale tints which can hardly be distinguished from white. A similar range also occurs in the pink- and violet-flowered varieties. The paler tints can usually be distinguished by examination of the buds, since in this stage the color is more distinct, or by dipping the petals in a dilute solution of hydrochloric acid, which deepens the color. These pale tints must be dis-

tinguished from true white forms in accurate genetic investigations of flower color. The writer has used the color standards of Ridgway (*18*) for comparing flower and seed colors of flax.

The anthers of the flax flower, also, are either blue, pale blue, yellow, or nearly colorless. Most commonly the pollen is similar in color to the anther walls, but this is not always the case.

The flax boll or capsule has five chambers or segments and each segment has two seeds which are separated by a low partition called the septum. In some varieties the septa are distinctly ciliate or hairy on the margins; in others they are smooth or nonciliate. When ripe, the flax boll is either dehiscent, opening and shedding its seeds when ripe, as in the variety Crepitans; semidehiscent, as in the fiber flaxes; or indehiscent, as in most Argentine and Indian varieties.

The inheritance of these characters has been investigated with great care by Dr. Tammes.

FIGURE 7.—Tine Tammes, University of Groningen, Netherlands, who has made an extensive investigation of the genetics of flax, including the wild species *Linum angustifolium*. Her publications on the inheritance of flower color, seed color, and other characters in flax are classics of science in their clear interpretation of complex genetic problems.

Factors Determining Petal Color

Tammes (*25*) has determined eight hereditary factors—A, B_1, B_2, C, D, E, F, and H—that in different combinations account for 32 genotypically different forms with colored petals and a number of forms with white petals. The same factors also account for differences in other characters (fig. 8).

The principal pure lines produced by Tammes in her investigations have very kindly been furnished the writer. A list of these, given in table 1, will help to make clear the effect of the several factors on color of petals, anthers, and seeds.

TABLE 1.—*Pure lines produced by Tammes*

C. I. no.	Tammes type	Factor composition [1]																Description: Petals	Anthers	Seeds
765	1	A	A	B_1	B_1	B_2	B_2	C′	C′	D	D	E	E	F	F	H	H	Blue	Blue	Brown.
766	2 (1×5)															*h*	*h*	do	Yellow	Do.
768	4	*a*	*a*															Light blue	Blue	Do.
769	5											*e*	*e*			*h*	*h*	Pale blue	Yellow	Do.
770	6													*f*	*f*			Lilac	Blue	Do.
771	7	*a*	*a*											*f*	*f*			Light lilac	do	Do.
772	8									*d*	*d*							Pink	Yellow	Do.
773	9 (6×8)									*d*	*d*			*f*	*f*			Deep pink	do	Light brown.
774	10							*c′*	*c′*									White, flat	Blue	Brown.
775	11			b_1	b_1													White, crimped	Yellow	Greenish yellow.
776	12					b_2	b_2											do	do	Brown.
777	13			b_1	b_1			*c′*	*c′*									White, flat	do	Greenish yellow.
778	14							*c′*	*c′*	*d*	*d*							do	do	Grayish brown.

[1] Only the recessive factors are shown that actually determine the character differences from common blue, C. I. 765, in which all factors are present.

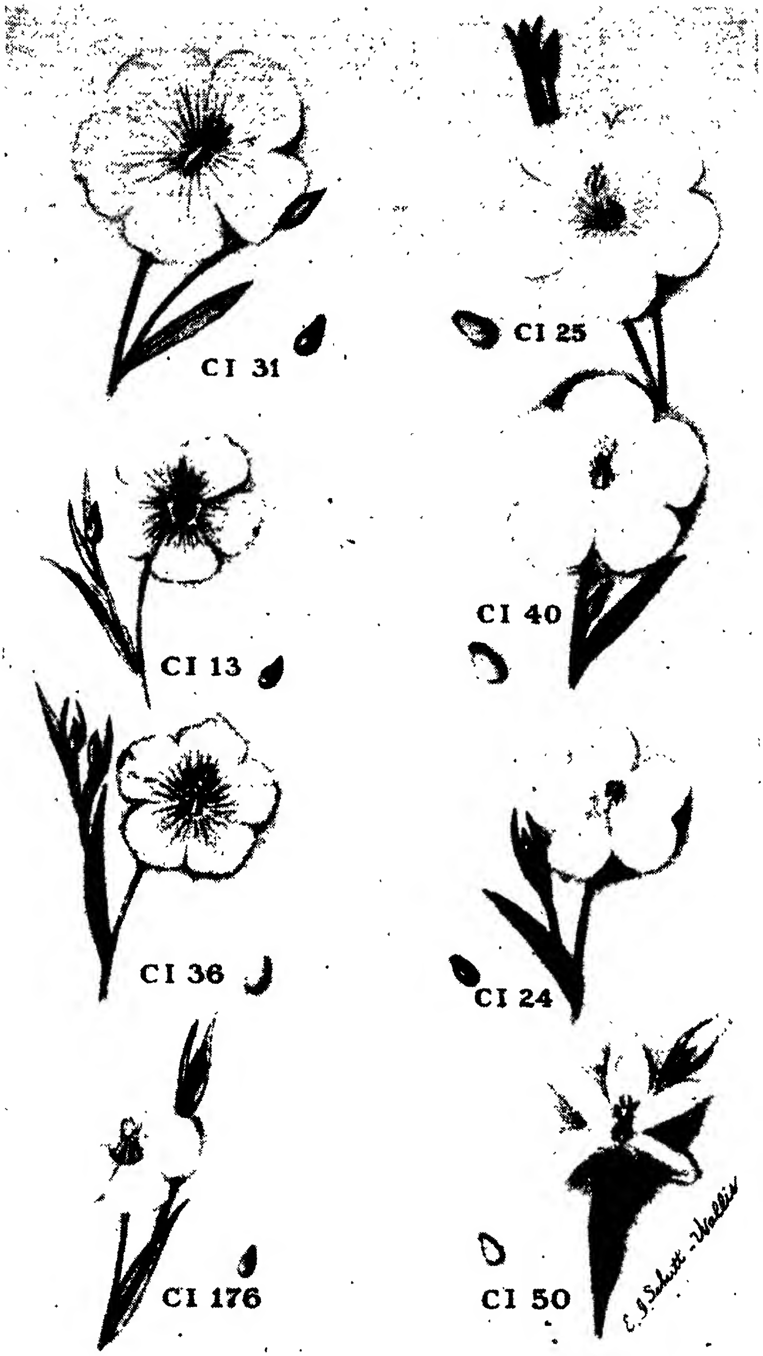

FIGURE 8.—Typical flowers of flax varieties: C. I. 31, Crete; petals and anthers blue. C. I. 25, Williston Golden; petals pale pink, anthers yellow. C. I. 13, N. D. R. No. 114; common blue. C. I. 40, Hoshangabad; petals pale pink, anthers yellow. C. I. 36, Abyssinian Yellow-seed; petals and anthers blue. C. I. 24, Ottawa White-flower; common white, anthers blue. C. I. 176, Selection C. I. 19-47; petals pale blue, anthers yellow. C. I. 50, Kashgar; petals "crimped" white, anthers yellow.

The factors B_1, B_2, and C' are basal factors, all necessary to produce color in the petals. If any one of them is recessive (b_1, b_2, or c'), the petal color is white. The factors D and F determine the tint of the petals. If the basal factors are present and d is recessive, the petal is pink; if D is present and f recessive, the petal is lilac. If B_1, B_2, C_1, D, and F are all present, the petal is blue. The factor F lessens the intensity of color in the petals, whereas the factors A and E are color intensifiers, E having a stronger effect than A.

In most forms with blue, lilac, or pink petals, the veins of the petals are of a darker tone and sometimes of a different hue than the space between the veins. In the true white-petaled forms, the veins are white or colorless. In some colored forms the veins are of the same tone as the space between, so that the petal is a uniform color, apparently without veins. This occurs when the factor $C'c'$ is heterozygous; the veins are then not apparent. When other factors for petal color are involved, the veins are usually darker than the space between in both the homozygous and the heterozygous condition.

Factors Determining Petal Shape

The shape of the petals is determined by the interaction of four of the factors that influence petal color. If B_1, B_2, C', and D are all present, as in most common flax varieties, the petals are broad and flat. If either b_1 or b_2 is recessive in the presence of both C' and D, the petals are narrow and "crimped"—inrolled at the outer margins. If either c' or d is recessive, however, the petals are flat, regardless of whether B_1 or B_2 are present or recessive.

Factors Determining Anther Color

Blue color in the anthers depends on the interaction of three of the factors that influence petal color—B_1, B_2, and D—and an additional factor, H. If any one of these four factors is recessive, the anthers are yellow. The white-petaled types in which b_1 or b_2 are recessive, and the pink types in which d is recessive, all have yellow anthers. White-petaled types in which B_1, B_2, D, and H are present but c' is recessive, and lilac or blue forms in which C' or both C' and F are present, have blue anthers. All types in which h is recessive have yellow anthers.

Factors Determining Seed Color

The inheritance of seed color was found by Tammes to depend upon the interaction of two of the factors influencing petal color, B_1 and D, as well as a basic factor G, and two or more additional polymeric factors that influence the intensity of color. If g is recessive, the seed is yellow because the yellow cotyledons are visible through the colorless seed coat. If G is present, the seed may still be yellow if the polymeric factors are absent. If B_1, D, and G are all present, the seed colors form a series from light yellow to blackish brown, but generally the tone is reddish brown. If b_1 is recessive, the seed colors also form a series from light to dark but of a greenish tone, except in the very light ones. If d, or both d and b_1, are recessive, the seed colors form a series ranging from light yellow to dark brown, but without the reddish cast characteristic of the series in which B_1, D, and G are dominant. Seeds with variegated seed coats also occur in

flax. This condition apparently is caused, in some instances, by climatic conditions that affect maturity of the seed. In other cases, the cause of variegation appears to be genetic, or a combination of genetic and environmental factors. A deficiency in the number of plants with crimped white petals and greenish-yellow seed, noted in crosses involving type 11 (C. I. 775), indicated a semilethal effect resulting from the concurrence of factors b_1 C'. No deficiency occurred in presence of B_1, or when both factors were recessive.

Tammes' factors for flower and seed color have been found to hold true in a great number of crosses made by J. C. Brinsmade, Jr., at the Northern Great Plains Field Station, in which he used varieties of different origin than those of Tammes. Shaw et al. (*20*) have investigated the inheritance of flower and seed colors in varieties of Indian linseed. Their studies included the color of the filaments, style, and stigma. They have suggested 10 or 11 additional factors, and the problem becomes more complex. Some of the factors postulated by Shaw behave in essentially the same manner as Tammes' factors, but whether they are identical can be determined only by crosses with the types used by Tammes. Since the publication of the paper by Shaw the present writer has sent Shaw seed of Tammes' varieties and has sent Tammes seed of the Indian types, so that each can determine, by means of crosses, the differences and similarities that exist in the several types.

In interpreting the results according to Tammes' factors, some confusion occurs because of difference in terminology. Tammes has used the term white to designate complete absence of color. The Indian type 1, described by Shaw (*20, p. 4*) as "white with pink tinge," and type 12, described as "very narrow white with blue tinge," are genetically not true whites according to Tammes' terminology. Indian type 13, which has narrow "crimped" true white petals, was not used as a parent in the crosses described by Shaw. The present writer, however, made crosses of Tammes' "crimped white" (C. I. 775) with Indian types 12 and 13, and in both cases the F_1 progeny has broad blue petals and blue anthers, indicating that both are distinct from Tammes' "crimped white" in petal characters.

Dehiscence of the Boll

Three quite distinct types of flax bolls can be distinguished according to the nature of their dehiscence. In the first type, variety Crepitans, the bolls are completely dehiscent, the segments separating widely and scattering the seeds as soon as the boll is ripe. In the second type, which includes most of the varieties grown for seed or fiber in the United States, the bolls are semidehiscent, that is, the boll opens at the apex and the five segments separate slightly along their margins. In the third type, including most of the Indian and Argentine varieties, the boll is indehiscent, remaining tightly closed when ripe (fig. 9). In both the dehiscent and the semidehiscent types, the bolls open when ripe and dry but close completely when wet by rain or dew. Flax varieties with indehiscent bolls are more difficult to thresh than semidehiscent varieties. This is especially true of some of the Indian varieties, including Punjab, C. I. 20, which is grown extensively in California.

In crosses described by Tammes between the variety Crepitans, having dehiscent bolls, and varieties having indehiscent bolls, the F_1

plants had dehiscent bolls of intermediate form. The F_2 plants comprised a fairly complete range of variation from the wide dehiscence of the Crepitans type to the indehiscence of the other parent. The F_3 generation indicated that the Crepitans form differed from the others in respect to boll dehiscence by at least two, and probably by three or four, polymeric [6] factors.

The genetic difference between the semidehiscent and indehiscent types may be of economic importance on account of the difference in ease of threshing. In crosses made by J. C. Brinsmade, Jr., at Mandan, N. Dak., between the Buda variety, with semidehiscent bolls, and Rio, indehiscent, semidehiscence appeared to be dominant. Progenies in subsequent generations approximated a ratio of 15 semidehiscent to 1 indehiscent. From this cross a high-yielding wilt- and rust-resistant strain, with nearly indehiscent bolls that thresh readily, has been produced.

FIGURE 9.—Three types of flax bolls (capsules) which are characteristic of groups of flax varieties: (1) Bolls dehiscent as in *A*, (2) bolls semidehiscent, subglobose (*B*, *C*, and *D*), and (3) bolls indehiscent, ovoid (*E*, *F*, and *G*). *A*, Crepitans; *B*, Roman Winter; *C*, Redwing; *D*, Bison; *E*, Indian type 46; *F*, Argentine; *G*, Lino Grande.

Smooth Ciliate Septa

In most American systematic botanical works, the bolls of *Linum usitatissimum* are described as having smooth or nonciliate septa. This is not true. In most cultivated varieties the septa are ciliate, though in a few they are smooth. In Crepitans, and in several strains of common or Russian linseed, Newland, Damont, and N. D. 155, the septa are smooth. Tammes (*23*) found that the ciliate condition was dominant over smooth and segregated in a 3 to 1 ratio in F_2. In a cross of Bison, ciliate, with Newland, smooth, Brinsmade obtained in the F_2 three plants with ciliate septa to one smooth. The same results have been obtained by Arny and others.

INHERITANCE OF DISEASE RESISTANCE

From the previous discussion of breeding work, it is clear that the development of improved disease-resistant varieties has been the most important problem in flax investigations in the United States.

[6] In a letter of Dec. 23, 1935, Dr. Tammes writes: "The term polymeric factors = multiple factors (not multiple allelomorphs). The term was first used by Lang in 1911 and generally applied in Europe. Here, also, the term multiple factors is used, but my experience is that multiple factors is sometimes confounded with multiple allelomorphs."

Flax wilt is of greater practical significance than any other disease, though flax rust, heat canker, and pasmo also cause some damage.

Wilt Resistance

The work of Tisdale (*26*) accomplished much toward clarifying the problem of why some varieties were wilt-resistant only under certain conditions. The relation of temperature to the infecting power of the wilt fungus was most significant. Wilt-susceptible flax grown at temperatures below 60° F. escaped injury from wilt. The same variety grown at 68° succumbed completely. The optimum temperature for growth of the fungus was about 80°, and it would grow at temperatures as high as 98°.

In crosses between wilt-resistant and susceptible strains, Tisdale found the F_1 was entirely resistant in some crosses and in others entirely susceptible. The F_2 generation showed great diversity of resistance and susceptibility, with no evidence of simple genetic ratios. No F_3 generation was reported. The conclusion, however, that "wilt resistance in flax is an inheritable character which is apparently determined by multiple factors" was a reasonable hypothesis.

Barker (*1*) grew, on wilt-infected soil, a number of individual selections of wilt-free and partially wilted plants of several varieties. The progeny showed great variation in percentage of wilt in different lines. The results indicated, however, that the progeny of nonwilted and partially wilted plants were not essentially different. Selection within a strain increased from a single plant apparently had no effect on wilt resistance. Different varieties, however, apparently bred true for different degrees of wilt resistance or susceptibility.

The investigations of Burnham (*5*) on the inheritance of wilt resistance in flax also showed that selected strains bred true for different degrees of wilt resistance. A significant point was made by Burnham—that wilting in pure-line resistant strains is not due to genetic segregation. In crosses between strains of different degrees of resistance the F_1, F_2, and F_3 generally showed an intermediate degree of wilting. Results in F_3 indicated that some of the segregating lines were as resistant as the resistant parent.

It has been observed that flax varieties or selections which were fairly wilt-resistant when first developed appear to become less resistant after a few years, or if grown in a different locality. Moreover, the relative resistance of different varieties is not likely to be the same when grown on flax-sick soil at St. Paul, Minn., and at Fargo and Mandan, N. Dak. The apparent lowering of resistance and the relative difference in resistance in different localities may possibly be explained by the investigations of Broadfoot (*4*), who found, over a wide area, at least nine physiologic forms of the wilt organism, which differed in their ability to infest different varieties of flax. The distribution and virulence of the several physiologic forms of the wilt organism is another problem in breeding for wilt resistance. Fortunately, we have varieties, such as Bison, Buda, and Argentine, which are resistant to wilt over a wide area, and thereore are valuable parents for breeding new wilt-resistant varieties.

Rust Resistance

In breeding for resistance to rust (*Melampsora lini*), flax breeders are fortunate in having varieties that are immune, or—to be con-

servative—let us say, practically immune. In several crosses made at the Agricultural Experiment Station, St. Paul, Minn., Henry (*10*) found immunity dominant in the F_1, and segregation either in a 3 to 1 or in a 15 to 1 ratio in the F_2 generation. In a cross between a selection of Argentine, immune, and the fiber flax, Saginaw, susceptible, the F_1 was immune and the F_2 population was approximately 15 immune to 1 susceptible, indicating a two-factor difference for rust immunity. In a cross between a rust-immune variety called Bombay—not of Indian type but probably a natural hybrid—and Winona, very susceptible, all plants in F_1 were immune, and the F_2 had 3 immune to 1 susceptible, indicating a single-factor difference. In another cross of Ottawa 770B, immune, by Saginaw, susceptible, a ratio of 3 immune to 1 susceptible was obtained in the F_2 population. The rust-immune single-line strains selected from these crosses by Henry and H. A. Rodenhiser are available under C. I. nos. 651 to 687, inclusive.

Similar results have been obtained by A. C. Arny, J. C. Brinsmade, Jr., and others. It appears, therefore, that it is not difficult to obtain practical immunity to rust, and this should be given careful consideration by flax breeders in the development of new varieties.

From an extensive collection of flax rust obtained from many different sources, Flor (*8*) has segregated 14 physiologic forms that may be distinguished by their reaction on eight differential varieties of flax. Fortunately for the flax breeder, several varieties of flax are immune to all of the rust forms.

SIZE OF SEEDS AND OIL CONTENT

Tammes (*23*), in studying the length of seeds in crosses of *Linum angustifolium* (2.4 mm) by Egyptian (6.1 mm), and by common flax (4.1 mm), found the F_1 nearly intermediate in each case. The F_2 population had a wider range in length of seeds but was still intermediate in type. The author says: "The genetic investigation showed that differences both in length and width of the seed are based upon some few polymeric factors" (fig. 10 and table 2).

The oil content of flaxseed may range from 33 to 44 percent or more, depending on the variety of flax and the climatic conditions under which it is grown. As previously noted, large-seeded varieties in general yield a higher percentage of oil than small-seeded varieties. The relative size or volume of flax seeds usually is expressed as the weight in grams of 1,000 seeds. Seeds of different varieties may be classed as small, 2.5 to 4.5 grams; midsize, 4 to 7; large, 6 to 9; or very large, 8 to 12 grams per 1,000 seeds (fig. 10). The writer has found a high correlation between seed size and oil content of different varieties. In a group of 124 varieties and strains grown at San Antonio, Tex., in 1926, the weight of 1,000 seeds ranged from 3.5 to 7.5 grams and the oil content from 36 to 44 percent, the correlation being $+0.696 \pm 0.031$. Johnson (*12*), in a study of 46 varieties at University Farm, St. Paul, Minn., reported a correlation between percentage of oil and weight of 1,000 seeds of $+0.716$ for the crop of 1929, and $+0.778$ in 1930.

In breeding flax for seed production, it is important to select strains with medium large seeds in order to obtain a satisfactory yield of oil.

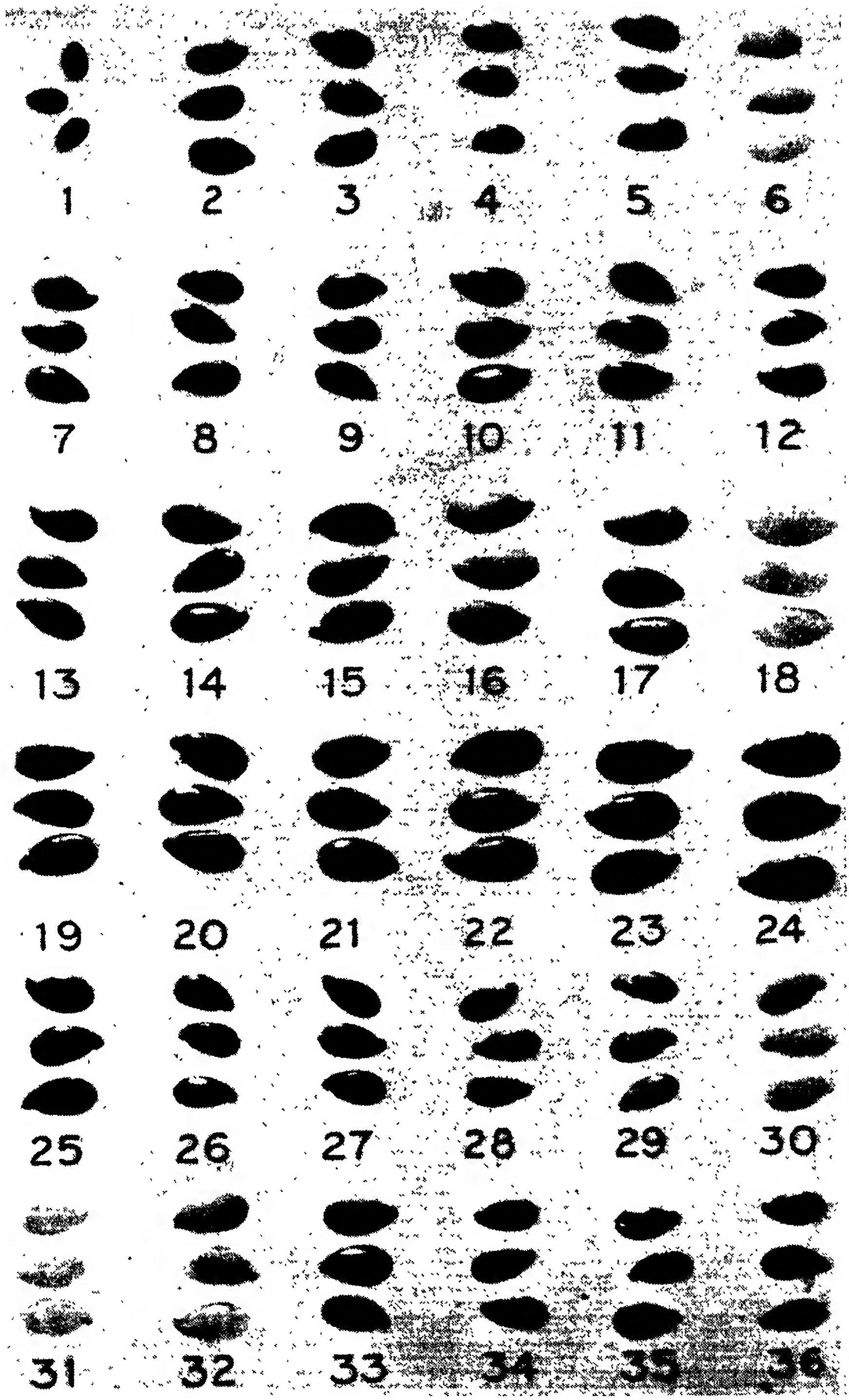

FIGURE 10.—Seeds of *Linum angustifolium* and of 35 distinct varieties of flax (*L. usitatissimum*), showing great range in size and color of seeds. (See table 2.) The seed was grown under irrigation at Bozeman, Mont., in 1930. × 2.

TABLE 2.—*Flaxseeds of types and varieties shown in figure 10*

No. on figure	Variety	C. I. no.	Color	Length	Weight of 1,000 seeds
				Mm	*Grams*
1	Linum angustifolium	698	Brown	2.5	1.50
2	Crepitans (dehiscent)	295	do	4.0	4.30
3	do	469	do	4.1	5.21
4	Roman winter	470	do	3.7	3.74
5	Abyssinian brown	302	do	4.3	5.27
6	Abyssinian yellow	300	Yellow	4.2	5.21
7	Linota	244	Brown	4.2	4.40
8	J. W. S.	388	do	4.2	4.38
9	Redwing	320	do	4.2	5.18
10	Bison	389	do	4.7	7.02
11	Newland	188	do	4.4	5.33
12	Novelty	140	do	4.6	6.26
13	Indian type 12		do	4.4	6.26
14	Indian type 68		do	4.9	6.95
15	Indian type 53		do	5.3	7.32
16	Indian type 9		Fawn	5.3	9.25
17	Indian type 13		Brown	5.2	9.13
18	Indian type 1		Clear yellow	6.0	10.76
19	Argentine	390	Brown	5.0	8.15
20	Malabrigo	346	do	5.0	8.18
21	Argentine	342	do	5.1	8.30
22	Lino Grande	381-2	do	5.8	11.55
23	Moroccan	376-2	do	5.9	9.90
24	Cyprus	689	do	6.1	11.36
25	Diadem	321	do	4.5	7.56
26	N. D. R. 714	399	do	4.0	4.55
27	Common white	329	do	4.1	4.40
28	Crimped white	392	Greenish yellow	4.1	4.42
29	do	330	do	4.1	4.70
30	Ottawa 770B	355	Yellow	4.6	5.80
31	Bolley Golden	644	do	4.2	7.25
32	Williston Golden	25	Chamois yellow	4.9	7.96
33	Long 66	337	Mottled brown	4.6	7.13
34	Tall Pink	451-3	"Dresden brown"	4.1	4.24
35	Deep Pink	336	do	4.0	4.28
36	Common Pink	479	"Mummy brown"	4.2	4.00

This character should be combined with desirable agronomic characters, disease resistance, and high acre yield. The large seeded or very large seeded varieties that are now available are generally inferior in acre yield, especially in hot dry seasons. Under such conditions, they produce fewer bolls and fewer seeds per boll than the smaller seeded varieties.

INHERITANCE OF QUALITY OF OIL

The drying quality of linseed oil is considered to depend on the quantity of oxygen it will absorb in the process of drying to form the characteristic paint film. However, the chemist determines the relative drying quality of oils by the absorption of iodine (instead of oxygen) per unit quantity of oil. This is known as the iodine number. The iodine number may range from 150 to 200 or more in extreme samples of linseed oil. The drying quality, or iodine number, is determined both by the variety of flax and by the climatic conditions under which the crop is grown. Johnson (*12*) found a small but significant negative correlation (−0.3087) between iodine number and weight of 1,000 seeds—that is, the smaller seeded varieties produced oil of somewhat better drying quality than the large-seeded varieties.

Arny [7] has investigated the inheritance of iodine number in crosses involving Bison, of low iodine number; Ottawa 770B, C. I. 355, medium; Pale Blue, C. I. 423, high; and Ottawa 829C, C. I. 391, high. He found that low iodine value appeared to be dominant. In the backcrosses with the parents of medium or high iodine number, a ratio of approximately 1:1 was obtained. Arny also found an apparent linkage of yellow seed coat with high or medium iodine number. His results are reported in table 3 (p. 775).

INTERSPECIFIC CROSSES

The number of chromosomes in species of *Linum* may be an indication of close or distant relationship of different species. It is noteworthy that of all the wild species, *L. angustifolium* is the only one which will cross readily with common flax. Tammes (*25*) in 1928 reviewed the literature in regard to chromosome numbers in *Linum* as known at that time. Kikuchi (*13*) in 1929 reported studies of additional species, and the writer (*6*) has added two species and three varieties of common flax as determined by A. E. Longley.

Most investigators agree that varieties of common flax, *L. usitatissimum,* and the closely related species *L. angustifolium* have 15 chromosomes in the reproductive cells and 30 in the plant cells, although 16 and 32 have been observed by some writers, as noted by Tammes and by Kikuchi. It is of interest that *L. rigidum* and *L. sulcatum* have 15 chromosomes (haploid) as determined by Longley, although these North American species appear quite distinct from each other, and both are very different from common flax. Several species, including *L. perenne* and *L. lewisii,* have 9 chromosomes (haploid), and 8, 10, 14, and 18 have been reported in other species of *Linum.*

Numerous interspecific (between species) crosses have been attempted by several investigators, but generally without success—conceptio nulla, or failure to conceive, as quoted by Tammes. Kikuchi (*13*), however, apparently was able to make a successful cross between *L. perenne* and *L. alpinun,* although the F_2 population had not been grown at the time of his publication.

J. C. Brinsmade, Jr., working at the Northern Great Plains Field Station in 1927 and 1928, attempted to make crosses between several species of *Linum* but without success. The crosses tried included the species *lewisii, perenne, rigidum, usitatissimum, angustifolium,* and *grandifolium.* Only in the cross of *L. angustifolium* and common flax (*usitatissimum*) were viable seeds obtained. In some cases the bolls of common flax were partly developed, but the few seeds obtained were shriveled and failed to germinate. The subject of interspecific crosses is reviewed more extensively in the papers by Tammes (*25*) and Kikuchi (*13*).

[7] Paper read Nov. 17, 1934, before American Society of Agronomy.

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Appendix

Botanical Groups of Flax

FIBER FLAX:

1. *Textile fiber.*—Grown chiefly for linen fiber. Plants tall (30-40 inches), stems small, unbranched, that is, without basal branches when grown in thick stand; flowers funnelform, blue or white; bolls semidehiscent, the septa ciliate or smooth; seeds small, brown.

   a. Flowers blue.

   Typical varieties: J. W. S. (C. I. 388), Saginaw (C. I. 449), Dalgonetz (C. I. 498), Cirrus (C. I. 727).

   b. Flowers white.

   Typical varieties: Pinnacle (C. I. 693), Tammes White (C. I. 329).

SEED FLAX OR LINSEED:

2. *Short fiber.*—Plants of short fiber type, midheight to tall (24-32 inches), stems small; flowers funnelform, blue or white; bolls semidehiscent, septa ciliate or smooth; seeds brown, small.

   a. Flowers blue.

   Typical varieties: Linota (C. I. 244), N. D. R. 114 (C. I. 13), Minn. 281 (C. I. 438), N. D. R. 726 (C. I. 412), Redwing (C. I. 320).

   b. Flowers white.

   Typical varieties: Ottawa White-flower (C. I. 24), N. D. R. 714 (C. I. 399).

3. *Common or "Russian".*—Plants midheight (24–32 inches), stems stout, with usually two or more basal branches; flowers funnelform, blue; bolls semidehiscent, septa smooth; seeds brown, small to midsize. Susceptible to wilt or only slightly resistant.

   Typical varieties: Newland (C. I. 188), Reserve (C. I. 19), N. D. R. 52 (C. I. 8), Novelty (C. I. 140).

4. *Mediterranean.*—Plants short to midheight (20–30 inches); stems stout, with two or more basal branches; flowers funnelform, large, blue; bolls large, indehiscent (or semidehiscent in a few varieties); septa ciliate or smooth; seeds brown, midsize to large.

   Typical varieties: Cyprus (C. I. 688), Morocco (C. I. 370), Giza (C. I. 378), Crete (C. I. 31).

5. *Argentine.*—Plants short to midheight (20–30 inches); stems stout, with two or more basal branches; flowers blue, large, flat (instead of funnelform as in groups 1 to 4); bolls large, indehiscent, septa ciliate; seeds brown, large. Plants immune to rust in most strains.

   Typical varieties: Malabrigo (C. I. 346), Rio (C. I. 280), Argentine (C. I. 462), Minn. 25–330 (C. I. 690), Lino Grande (C. I. 381).

6. *Indian.*—Plants short (10–20 inches); stems stout with two or more basal branches; flowers tubular to funnelform; bolls indehiscent, septa ciliate or smooth; seeds small to very large.

   a. Seeds yellow, large; petals pale pink.

   Typical varieties: Hoshangabad (C. I. 40), Luteum—types 1, 2, and 3 of Howard and Kahn (*11*).

   b. Seeds brown, small to large; petals blue, pale blue, or violet.

   Typical varieties: Punjab (C. I. 20), Albidum (type 12), Sativum (type 121), Jalaun Sel. (C. I. 156).

7. *Abyssinian.*—Plants short (12–20 inches), much branched and leafy; stems small, with two or more basal branches, and much-branched panicle; flowers funnelform, blue; bolls small, semidehiscent, septa ciliate; seeds small, yellow or brown.

   a. Seeds yellow.

   Typical variety: Abyssinian Yellow-seed (C. I. 36).

   b. Seeds brown.

   Typical variety: Abyssinian Brown-seed (C. I. 302).

8. *Golden.*—Plants short to midheight (12–28 inches); stems stout, with two or more basal branches; flowers funnelform, pale pink, anthers yellow; bolls indehiscent, septa ciliate or smooth; seeds midsize, yellow, chamois yellow, mottled or mummy brown.

   Typical varieties: Bolley Golden (C. I. 644), Long No. 66 (C. I. 337), Williston Golden (C. I. 25), Pale Pink (C. I. 649).

9. *"Crimped White."*—(Petals white, inrolled or "crimped.") Plants midheight to tall (20–40 inches); stems stout or slender; flowers white, petals narrow, inrolled, anthers yellow; bolls semidehiscent, septa ciliate or smooth; seeds small, greenish yellow (ecru-olive), yellow or brown.

   Typical varieties: Ottawa 770B (C. I. 355), Minn. 25–125 (C. I. 392), Tammes Crimped (C. I. 330), Saginaw × Ottawa 770B (C. I. 687).

10. *Dehiscent.*—(*Linum usitatissimum*, var. *crepitans.*) Plants annual, midheight (20–30 inches); stems stout; flowers small, deep lavender, bolls fully dehiscent, septa smooth; seeds brown, midsize, somewhat oval in outline.

    Typical varieties: C. I. 295 from Vladivostok, C. I. 469 from Germany, C. I. 506 from Ukraine.

11. *Linum angustifolium*, plants annual, short to midheight (10–24 inches); stems slender with two or more basal branches; flowers funnelform, small, deep lavender; bolls dehiscent, septa ciliate; seeds very small, light brown.

    Typical varieties: C. I. 698 from Vavilov, and C. I. 779 from Tammes.

TABLE 3.—*Correlation of factors affecting certain characters—seed color, ciliate or smooth septa, and iodine number of oil in flax* [1]

	Year	Brown	Yellow	X^2	P
Goodness of fit for segregation to a 1 : 1 ratio in backcrosses, indicating a one-factor difference for each pair of characters.					
1. Seed color:					
Bison (brown) × C. I. 355 (yellow) × 355	1933	68	67	0.007	+0.9
C. I. 355 (yellow) × C. I. 423 (brown) × 355	1934	27	32	.424	+.5
Bison (brown) × C. I. 391 (yellow) × 391	1934	96	83	.944	−.3
	Year	Ciliate	Smooth	X^2	P
2. Septa:					
Bison (ciliate) × C. I. 355 (smooth) × 355	1933	66	69	0.067	−0.8
C. I. 355 (smooth) × C. I. 423 (ciliate) × 355	1934	31	28	.153	+.9
Bison (ciliate) × 391 (smooth) × 391	1934	90	89	.006	+.9
	Year	Low	High	X^2	P
3. Iodine number of oil:					
Bison (low) × C. I. 355 (medium) × 355	1933	60	65	1.666	−0.2
C. I. 355 (medium) × C. I. 423 (high) × 355	1934	28	31	.153	+.9
Bison (low) × C. I. 391 (high) × 391	1934	91	88	.050	+.8

	Year	Yellow, ciliate	Yellow, smooth	Brown, ciliate	Brown, smooth	X^2	P
B. Independence of inheritance of characters in backcrosses:							
1. Seed color and ciliate or smooth septa independently inherited:							
Bison (brown, ciliate) × C. I. 355 (yellow, smooth) × 355	1933	29	38	37	31	1.673	−0.20
C. I. 355 (yellow, smooth) × C. I. 423 (brown, ciliate) × C. I. 355	1934	16	16	15	12	.181	−.70
Bison (brown, ciliate) × C. I. 391 (yellow, smooth) × 391	1934	37	46	53	43	2.012	−.20
	Year	Yellow, high	Yellow, low	Brown, high	Brown, low	X^2	P
2. Seed color and iodine number closely linked:							
Bison (brown, low) × C. I. 355 (yellow, medium) × 355	1933	64	3	12	56	83.186	−0.01
C. I. 355 (yellow, medium) × C. I. 423 (brown, high) × 355	1934	25	7	6	21	18.353	−.01
Bison (brown, low) × C. I. 391 (yellow, high) × 391	1934	75	4	13	87	118.553	−.01
	Year	Ciliate, high	Ciliate, low	Smooth high	Smooth low	X^2	P
3. Ciliate or smooth septa, and iodine number independently inherited:							
Bison (ciliate, low) × C. I. 355 (smooth, medium) × 355	1933	36	31	40	28	0.356	−0.50
C. I. 355 (smooth, low) × C. I. 423 (ciliate, high) × C. I. 355	1934	15	13	19	12	.359	+.50
Bison (ciliate, low) × C. I. 391 (smooth, high) × 391	1934	44	48	44	43	.135	+.70

[1] From a paper read by A. C. Arny, agronomist, Agricultural Experiment Station, St. Paul, Minn before American Society of Agronomy at the Washington meeting, Nov. 17, 1934.

TABLE 4.—*Varieties of seed flax (linseed) and of fiber flax introduced or developed and distributed by the U. S. Department of Agriculture or State agricultural experiment stations*[1]

Type of flax, State, and station	Variety and C. I. no.	Year selected and year distributed	By whom developed	Method used and parent variety or source	Superior characters of the variety	Estimated acreage in the United States: 1929	Estimated acreage in the United States: 1935
Seed flax (linseed):							
Minnesota:							
Agricultural Experiment Station, St. Paul.	Primost, C. I. 12	1894, 1902	W. M. Hays	Selection from S. P. I. 10,006, White-blossom Dutch.	Uniform, productive, somewhat wilt-resistant.	*Acres* 100,000	*Acres* ----
	Winona, C. I. 179	1915, 1920	E. C. Stakman, H. K. Hayes, H. D. Barker.	Selection from Blue Dutch, Minn. 175.	Somewhat wilt-resistant	100,000	----
	Redwing, C. I. 320	1915, 1924	do	Selection from S. P. I. 10,006	Early, wilt-resistant, good drying quality of oil.	10,000	130,000
	Hybrids, C. I. 651–687	1924, 1932	A. W. Henry,* and H. A. Rodenhiser.	Hybrids of Saginaw, Winona, Ottawa 770B and Argentine.	Wilt-resistant and immune to rust.	----	----
North Dakota:							
Agricultural Experiment Station, Fargo.	N. D. R. 52, C. I. 8	1902, 1908	H. L. Bolley	Selection from "Common" North Dakota flax.	High yield, somewhat wilt-resistant.	500,000	----
	N. D. R. 114, C. I. 13	1902, 1912	do	do	Wilt-resistant, good quality of oil.	1,000,000	----
	Buda, C. I. 326	1906, 1921	do	Selection from S. P. I. 10,018	Wilt-resistant, rust-resistant, high yield.	200,000	100,000
	Bison, C. I. 389	1912, 1925	H. L. Bolley, O. E. Heggness.	Selection from seed obtained from Ghent, Belgium.	Very resistant to wilt, high yield.	10,000	1,700,000
	Linota, C. I. 244	1916, 1925	T. E. Stoa	Selection from N. D. 155, "Russian."	Wilt-resistant, high yield, early.	400,000	75,000
	Bolley Golden, C. I. 644	1924, 1932	H. L. Bolley, O. E. Heggness.	Hybrid selection	Yellow seed, wilt-resistant, good quality oil.	----	500
	Walsh, C. I. 645	1924, 1931	H. D. Long	do	Very large brown seed yielding high percentage of oil.	----	5,000
Northern Great Plains Field Station, Mandan.	Newland, C. I. 188	1914, 1927	Chas. H. Clark*	Selection from Reserve (C. I. 19–205).	High yield, rust-immune, good quality oil.	10,000	5,000
	Punjab, C. I. 20	1915, 1931	do	Selection from Indian (C. I. 20–1–1).	High yield, important variety in California.	----	40,000
	Abyssinian, C. I. 36	1915, 1933	do	Selection from Abyssinian (C. I. 36–23).	High yield, good quality of oil, adapted to California.	----	500
Fiber flax:							
Michigan:							
Agricultural Experiment Station, East Lansing.	Saginaw, C. I. 207	1909, 1920	A. E. Mayland, R. L. Davis.	Selection from Blue Dutch	Tall, high fiber yield, wilt-resistant.	----	----
	F. I. No. 3, C. I. 694	1918, 1931	R. L. Davis*	Selection from Riga Commercial.	High fiber yield of good quality.	----	----

	Pinnacle, C. I. 693	1924, 1931	B. B. Robinson*	Selection (probably as mixture) from Saginaw.	Early, high fiber yield, white blossom.		
Oregon: Agricultural Experiment Station, Corvallis.	F. I. 37	1924, 1934	do	Selection of cross of selected plants made in 1919.	High fiber yield and good spinning quality.		
	F. I. 47	1924, 1934	do	Selection	do		
	F. I. 51	1924, 1934	do	do	do		
	F. I. 54	1924, 1934	do	do	do		

[1] An asterisk (*) indicates by, or in cooperation with, the U. S. Department of Agriculture.

TABLE 5.—*Agronomic and botanical characters of certain flax varieties which are available in breeding for disease resistance, higher yield and quality of oil, and for fiber production*

Group and variety	C. I. no.	Reaction to disease		Height	Maturity
		Wilt	Rust		
Seed flax (linseed):					
Bison	389	Resistant	Susceptible	Midheight	Midseason.
Buda	326	do	Resistant	do	Do.
Redwing	320	Medium resistant	Susceptible	do	Early.
Newland	188	Susceptible	Immune	do	Midseason.
Rio (Argentine)	280	Resistant	do	Short	Do.
Malabrigo (Argentine)	696	do	do	do	Do.
Walsh	645	Medium resistant	do	do	Do.
Ottawa 770B	355	do	do	Midheight	Do.
Bolley Golden	644	do	do	Short	Early.
Abyssinian Yellow-seed	36	Susceptible	Susceptible	do	Do.
Punjab (Indian)	20	do	do	do	Do.
Type 55 (Indian)		Resistant	do	do	Do.
Type 68 (Indian)		Medium resistant	Immune	do	Do.
Pale Blue	423	do	Susceptible	Midheight	Do.
Pale Pink	649	do	Immune	do	Do.
Ottawa White	24	do	Susceptible	do	Do.
Fiber flax:					
J. W. S	388	Susceptible	do	Tall	Midseason.
Cirrus	727	Medium resistant	Resistant	do	Do.
Saginaw	207	do	Susceptible	do	Do.
Liral 9	730	Susceptible	Resistant	do	Do.
Pinnacle	693	Resistant	Medium resistant	do	Early.
Minnesota Hybrid Selection	687	do	Immune	do	Midseason.

Table 5.—*Agronomic and botanical characters of certain flax varieties which are available in breeding for disease resistance, higher yield and quality of oil, and for fiber production*—Continued

Group and variety	C. I. no.	Seed characters				Boll characters		Flower characters		
		Color	Size	Oil content	Iodine number	Dehiscence	Septa	Type	Petals	Anthers
Seed flax (linseed):										
Bison	389	Brown	Medium	High	Low	Semidehiscent	Ciliate	Typical	Dark blue	Blue.
Buda	326	do	Small	Medium	High	do	do	do	Blue	Do.
Redwing	320	do	do	do	do	do	do	do	Light blue	Do.
Newland	188	do	Medium	do	Medium	do	Smooth	do	Blue	Do.
Rio (Argentine)	280	do	Large	High	Low	Indehiscent	Ciliate	Large	do	Do.
Malabrigo (Argentine)	696	do	do	do	do	do	do	do	do	Do.
Walsh	645	do	Very large	do	do	Semidehiscent	do	do	do	Do.
Ottawa 770B	355	Yellow	Medium	do	Medium	do	Smooth	Crimped	White	Yellow.
Bolley Golden	644	do	do	do	High	do	do	Typical	Pale pink	Do.
Abyssinian Yellow-seed	36	do	Small	Medium	do	do	do	do	Blue	Blue.
Punjab (Indian)	20	Brown	Medium	High	Medium	Indehiscent	Ciliate	do	do	Do.
Type 55 (Indian)		do	do	do	do	do	Smooth	do	do	Do.
Type 68 (Indian)		do	do	do	do	do	do	Tubular	do	Do.
Pale Blue	423	do	Small	Low	High	Semidehiscent	Ciliate	Typical	Pale blue	Yellow.
Pale Pink	649	Yellow	do	do	do	do	do	do	Pale pink	Do.
Ottawa White	24	Brown	do	Medium	do	do	Smooth	do	White	Blue.
Fiber flax:										
J. W. S.	388	do	do	Low	Medium	do	do	do	Blue	Do.
Cirrus	727	do	do	do	do	do	do	do	do	Do.
Saginaw	207	do	do	do	do	do	Ciliate	do	do	Do.
Liral 9	730	do	do	do	do	do	do	do	do	Do.
Pinnacle	693	do	do	do	do	do	Smooth	do	White	Do.
Minnesota Hybrid Selection	687	Greenish yellow	do	do	do	do	do	Crimped	do	Yellow.

Stations, Flax Breeders, Breeding Methods, Commercial Varieties, Promising New Strains, and Objectives in Present Work

[An asterisk (*) indicates employee of, or cooperator with the U. S. Department of Agriculture]

UNITED STATES

Department of Agriculture, Washington, D. C.:

Early workers:

Charles R. Dodge*—in charge of fiber crops, Bureau of Plant Industry, 1889 to 1898, introduced several varieties of fiber flax and conducted extensive varietal cultural experiments in 18 States.

Charles H. Clark*—In charge of flax investigations, Division of Cereal Crops and Diseases, Bureau of Plant Industry, from 1913 to 1920. Selected Newland, Punjab (C. I. 20), and Abyssinian (C. I. 36).

Lyster H. Dewey*—In charge of fiber crop investigations, Bureau of Plant Industry, from 1902 to September 1935, when he retired. Introduced varieties of fiber flax and supervised selection and breeding of fiber flax in cooperation with the agricultural experiment stations of Michigan and Oregon.

Present workers:

J. C. Brinsmade, Jr.*—Working at the Northern Great Plains Field Station, Mandan, N. Dak., Mr. Brinsmade has made numerous crosses for the study of inheritance of wilt resistance, flower and seed colors, and other characters. New and promising wilt-resistant strains include C. I. 737, Buda Selection; C. I. 742, Buda × (19 × 112); C. I. 744, Selection from C. I. 161, a natural hybrid; and C. I. 739 (19 × 112) × 19. Object in present work: Breeding for wilt and rust resistance and for better drying quality of oil.

A. C. Dillman*—In charge of seed flax investigations, Division of Cereal Crops and Diseases, Bureau of Plant Industry, the writer has introduced many foreign varieties, and has made numerous crosses to study the inheritance of wilt resistance, rust resistance, dehiscence of the boll, and other characters.

H. H. Flor*—Working on the diseases of flax, in cooperation with the North Dakota Agricultural Experiment Station, Fargo, N. Dak., Dr. Flor has found that a number of varieties of flax are immune to different physiologic forms of flax rust. He has made crosses of Bison by rust-immune strains of Buda, Rio, and other wilt-resistant varieties, and has selected single-line strains in F_5 and F_6 which are immune from rust and wilt-resistant.

B. B. Robinson*—As plant breeder, Division of Cotton and Other Fiber Crops, Bureau of Plant Industry, in cooperation with the Oregon Agricultural Experiment Station, Mr. Robinson has selected several promising single-line strains of fiber flax, including his nos. 37, 47, 51, and 54, which have produced a high yield and excellent quality of fiber. One or more of these will be increased for commercial production. In cooperation with the Michigan Agricultural Experiment Station, 1924–31, Mr. Robinson selected Pinnacle, a white-flowered fiber flax.

CALIFORNIA:

University Farm, Davis.

Present workers:

L. G. Goar, B. A. Madson.

Object of present work: Selection for wilt resistance, high yield, and superior quality of oil of strains adapted to California conditions: (1) As a fall-sown crop under irrigation and (2) as a dry-land crop where irrigation is not available.

Imperial Valley Field Station, El Centro.

Early workers:

Waldo W. Weeth, foreman, August 1930 to July 1934; L. G. Goar, foreman 1926 to July 1930. Through informal cooperation between the Division of Cereal Crops and Diseases, United States Department of Agriculture, and the California Agricultural Experiment Stations, Mr. Goar conducted the fundamental experiments (1927 to 1930) which established Punjab (C. I. 20) as a crop adapted to cultivation under irrigation in the Imperial Valley. The extension of the crop and the solution of the practical problems of large-scale production were due largely to the work and enthusiasm of Mr. Weeth.

Present worker:

Allan R. Scott.

Object of present work: Selection of superior strains for the particular soil and climatic conditions of the Imperial Valley.

MICHIGAN:

Agricultural Experiment Station, East Lansing, also at Croswell and at Yale.

Early workers:

A. E. Mayland (1909)—Made numerous selections of fiber flax from commercial fields.

Leroy V. Crandall (1910–12)—Continued selection and testing by the centgener method of the selections made by Mayland.

Frank C. Miles * (1913–17)—Developed Saginaw from an original selection made by Mayland in 1909, and selected other (unnamed) strains of fiber flax.

Robert L. Davis * (1916–23)—Continued selection of fiber flaxes. Made crosses from which a tall pink-flowered strain (C. I. 451) was developed.

MINNESOTA:

Agricultural Experiment Station, University Farm, St. Paul.

Early workers:

W. M. Hays—Developed Primost, a short-fiber type of seed flax, by selection of a blue-flowered mixture or natural hybrid from White-flowered Dutch, S. P. I. 10,006.

H. D. Barker—Working with E. C. Stakman and H. K. Hayes, aided in the development of Redwing and Winona.

A. W. Henry—Made crosses of the rust-immune varieties, Ottawa 770B and Argentine, with the rust-susceptible varieties, Saginaw and Winona, from which the rust-immune single-line selections, C. I. Nos. 651 to 687, were developed.

Present workers:

A. C. Arny—Has made numerous crosses of Bison by Redwing, Ottawa 770B, Abyssinian Yellow-seed, Pale Blue (C. I. 423), and other varieties to develop disease-resistant strains of high oil content and a superior drying quality of oil. Selections in F_5 and F_6 generations are being compared with standard varieties in plot tests.

Clyde C. Allison—In a study of inheritance of wilt resistance, in all crosses in which Bison was used as one parent, resistance to wilt was partially dominant in F_1 and F_2, whereas in crosses where C. I. 679 (Saginaw×Ottawa 770B) was used as one parent, little or no resistance to wilt was obtained in F_1 or F_2.

W. M. Myers—In cooperation with Arny and Allison, Mr. Myers has studied the inheritance of rust and wilt resistance in crosses of Bison by Ottawa 770B, Newland, and other varieties.

E. C. Stakman—As plant pathologist, Dr. Stakman has cooperated with Barker, Henry, Allison, and others in the work of selection and breeding for wilt and rust resistance in flax, and has directed the investigations of the organisms which cause these diseases.

H. K. Hayes—As chief of the Division of Agronomy and Plant Genetics, Dr. Hayes has cooperated with Arny, Myers, I. J. Johnson, and others on the genetic problems of flax breeding and in the practical work of breeding new and superior varieties.

Object of present work: The object of the present breeding work is to develop a wilt-resistant and rust-immune variety which will have a high acre yield and will produce a high percentage of oil of superior drying quality so far as these characters can be combined in a single variety.

MONTANA:

Agricultural Experiment Station, Bozeman.

Present workers:

L. P. Reitz, A. H. Post, and Clyde McKee. The work of selection and breeding and the classification of flax varieties is carried on in cooperation with the Division of Cereal Crops and Diseases, United States Department of Agriculture. Introduced varieties are grown at this station, where conditions are particularly favorable for flax from the standpoint of freedom from diseases, and where the introduced seed is segregated (in quarantine) until its purity and freedom from disease is determined.

Object of present work: To develop early varieties adapted to cultivation in the higher irrigated valleys of Montana.

Judith Basin Branch Station, Moccasin.

Early worker:

Ralph W. May*—The variety Newland (C. I. 188), first selected by Charles H. Clark at the Northern Great Plains Field Station, Mandan, N. Dak., was increased by Mr. May, on the basis of superior yields at Moccasin (1922–26), and distributed by the Montana station in 1927.

NORTH DAKOTA:

Agricultural Experiment Station, Fargo.

Former workers:

A. M. Ten Eyck—Developed Damont, C. I. 3 (N. D. 1215) as a single-line selection in 1900 from N. D. 155. It was reselected for 2 or 3 generations and distributed as N. D. 1215.

H. D. Long—As assistant (1915–20) to H. L. Bolley, Mr. Long made many crosses and selections of yellow-seeded and large brown-seeded flaxes which are still available as breeding material. Several selections (C. I. Nos. 337, 354, and 400) have large yellow seeds and are moderately wilt-resistant. Rio, C. I. 280, is a selection of Argentine flax which is immune from rust and wilt-resistant. Walsh, C. I. 645, which has large brown seeds, was selected from a cross including four parent strains. It was distributed in 1931 and grown commercially to some extent in Walsh County, N. Dak.

Present workers:

H. L. Bolley—Botanist and plant pathologist at the North Dakota Agricultural Experiment Station from 1890 to the present time. Discovered and named, in 1900, the fungus, *Fusarium lini*, which causes flax wilt, and established the first flax-breeding nursery (plot 30) on wilt-infected soil. As agent for the United States Department of Agriculture in 1903, he made a study of flax production in Europe and introduced numerous lots of flaxseed, S. P. I. Nos. 9897 to 10381. In cooperation with the linseed industry of the United States, Professor Bolley made a study of flax production in Argentina in 1930 and introduced over 400 lots of flaxseed for trial at the North Dakota Station. By means of continued selection on wilt-infected soil, he developed the important commercial varieties North Dakota Resistant No. 52, N. D. R. 114, Buda, and—with O. A. Heggeness—Bison, Bolley Golden (C. I. 644) and other valuable strains. Bolley Golden is short in habit of growth in North Dakota, but is very promising under irrigation at the Imperial Valley Field Station, El Centro, Calif.

O. A. Heggeness—Working with H. L. Bolley since 1922, Mr. Heggeness assisted in developing the Bison variety, and since 1930 has made crosses of Bison by Argentine selections, Bolley Golden, and other varieties.

T. E. Stoa—Developed the Linota variety (possibly a natural hybrid) by selection from N. D. 155, and has made many selections of yellow-seeded strains of high oil content and good drying quality of oil.

L. R. Waldron*—Since 1933 has had charge of the flax-improvement work formerly carried on by T. E. Stoa. Has made further selections and crosses for the purpose of improving the yield and quality of oil.

T. H. Hopper*—As agricultural chemist, Professor Hopper is cooperating with the several flax breeders of the North Dakota Station and with the Division of Cereal Crops and Diseases, United States Department of Agriculture, in technical studies of the yield and quality of oil in hybrids, as determined by hereditary factors, and as influenced by climatic factors.

Object in present work: Improvement in resistance to wilt and other diseases, increased yield of seed, and higher percentage yield and improved drying quality of oil. Also to determine the inheritance of resistance to wilt and to different physiologic forms of flax rust.

OREGON:

Agricultural Experiment Station, Corvallis.

This station is testing varieties of seed flax (linseed) and in cooperation with the United States Department of Agriculture, B. B. Robinson in charge, is doing extensive work on the improvement of fiber flax.

WISCONSIN:

Agricultural Experiment Station, Madison.

Former workers:

W. H. Tisdale—As a graduate student, Tisdale in 1915–17 made probably the first detailed study of the inheritance of resistance to flax wilt, using North Dakota Resistant 114 as the resistant parent. He concluded (*26*) that "wilt resistance in flax is an inheritable character which apparently is determined by multiple factors."

Charles R. Burnham—Made several crosses of wilt-resistant single-line selections by wilt-susceptible varieties in a study of the inheritance of wilt resistance. He found that in the F_3 only a small percentage of the families were as resistant as the resistant parent. Most of the families fell in the susceptible class, while a few were intermediate in resistance (*5*).

Institutions, Breeders, Breeding Methods, Commercial Varieties, Promising New Strains, and Objectives in Other Countries

CANADA

Central Experimental Farm, Ottawa, Ontario.

Early worker:

Sir C. E. Saunders—In 1910 Saunders produced three important varieties by hybridization, namely: Ottawa 770B (C. I. 355) from a cross of La Platta A × Yellow-seed C; Diadem (C. I. 321), La Platta × White-flower B; and Ottawa 829C (C. I. 391) Yellow-seed C × Common S. He also selected Novelty (C. I. 322) from an introduction of Russian origin. Ottawa 770B has been used extensively in hybridization at the University of Minnesota, as it is immune to rust and has yellow seeds of high oil content.

Present worker:

W. G. McGregor—Has made crosses of Ottawa 770B, Bolley Golden, Cyprus (C. I. 689), Diadem, and other varieties for the purpose of developing disease-resistant, early-maturing varieties of high oil content and better drying quality of oil. Selections of F_4 generation have been grown for comparison and further selection.

University of Alberta, Edmonton.

Early worker:

O. S. Aamodt—In 1930 made crosses of Diadem by Bison and Buda and of Cyprus (C. I. 689) by Bison, Buda, and Rio.

Present worker:

A. W. Platt—Continued the selection work from crosses made by Aamodt.

SOUTH AMERICA

ARGENTINA: Ministerio De Agricultura, Buenos Aires.

The extensive commercial production of flaxseed in Argentina is chiefly of the Malabrigo variety (named from the village of Mal Abrigo, Santa Fé). In a letter of November 25, 1926, Carlos D. Girola remarked: "The flax Malabrigo is looked upon as a variety produced not through genetic processes, but through mechanical selection and adaptation." The types or varieties San Carlos, Lineta (small seed), Lino Grande (large seed), and Flor Blanca (white flower), are grown to a less extent than Malabrigo. Only recently has the improvement of flax by selection and breeding been undertaken by the Ministry of Agriculture at Pergamino and the other experiment stations.

URUGUAY:

Instituto Fitotecnico Y Semillero Nacional "La Estanzuela," Colonia.

Present worker:

Albert Boerger—Selected several strains of seed flax which are promising for commercial production in Uruguay and Argentina. Seed of these selections has been sent to the Division of Cereal Crops and Diseases by Dr. Boerger and grown under C. I. nos. 785 to 790, inclusive.

ASIA

INDIA: Imperial Institute of Agricultural Research, Delhi (formerly at Pusa).

Former worker:

Gabrielle L. C. Howard, with Abdur Rahman Khan, made a classical study of the varieties of Indian linseed (*11*). They selected and described 123 pure-line strains (self-pollinated under bags) and grouped these under 26 named varieties. The varieties Albidum (type 12) and Sativum (type 121), of superior yield, have been distributed for growing in the States of Bihar and Orissa. All of these selections have been grown by the writer in the United States and a few types (12, 55, and 121) have given promising yields at El Centro, Calif.

Present workers:

F. J. F. Shaw, Imperial Economic Botanist for India, with Abdur R. Khan and M. Alam, have made a genetic study of Indian linseed varieties (*20*) and have selected a number of promising hybrids for trial. Hybrid Nos. 10 (type 12 × 1), 21 (12 × 8), 55 (8 × 121) and 68 (22 × 121) have larger seeds of higher oil content than the parent varieties. He also selected a new strain (type 124) having small yellow seeds as a mutation from the variety Cyaneum (type 8).

R. B. Deshpande—As assistant to Dr. Shaw, Mr. Deshpande now has charge of the flax-breeding work and is testing 105 strains obtained as single-line selections from the crosses made by Dr. Shaw.

Object of present work: To obtain new varieties of high yield, large seed of high oil content, and resistant to diseases, especially rust and wilt.

Superior varieties in India: According to a report from Mr. Deshpande each Province has its own varieties adapted to the soil and climatic conditions of the locality. Howard's types 6, 12, and 121 do well in Bihar and Orissa, Assam, and the United Provinces. A selection known as E. B. 3 does well in Berar and Nagpur, whereas selections E. B. 477 and 776 are superior varieties in the United Provinces. It is not definitely known to what extent these new varieties are grown commercially, but it is probable that each covers a large acreage in the Province where it has been introduced.

JAPAN:

Hokkaido Agricultural Experiment Station, Kotoni, Sapporo.

This station is conducting breeding and selection work with fiber flax.

EUROPE

IRELAND: Ministry of Agriculture, Belfast.

Has carried on extensive selection work with fiber flax and has developed the improved varieties, Cirrus (C. I. 727) and Gossamer (C. I. 728).

Linen Industry Research Association, Lambeg, County Antrim.

The botanical division of this association, G. O. Searle, director, has developed several improved strains of fiber flax which have been distributed under the varietal names Pioneer (C. I. 723), Beatall (C. I. 724), Monarch (C. I. 725), Crown (C. I. 726), and Dominion.

HOLLAND:

University of Groningen, Groningen. Tine Tammes has made fundamental genetic studies of flax, and her pure-line strains of distinct flower and seed types have been generously furnished to other flax breeders for study and for use as breeding material. The writer has several strains under C. I. Nos. 765 to 778, inclusive, which are described in some detail on page 762 of this section.

J. C. Dorst, Council for Plant Breeding, Leewarden, has developed the varieties Concurrent, Alba, Bella, and Concordia. Concurrent, a white-flowered fiber flax, is now the leading commercial variety in the Netherlands. Other varieties which are recommended are Friesh white-flowered, Blenda, Texala, Hercules, and Giganta. The variety Giganta was developed, by P. J. Hylkema, Groningen.

FRANCE:

Fiber-flax production has been increased in recent years to about 50,000 acres, due largely to a bonus paid by the Government to farmers for growing this crop. Formerly much seed of fiber flax for sowing was imported, but since the work of L. Blaringhem (*2*) on seed selection there has been notable improvement in the flax crop, and domestic seed is now generally used. Michotte (*16*) has written an important work on the cultivation, improvement, and commercial handling of flax.

GERMANY:

The writer is not informed of the progress of flax-breeding work in Germany except through publications. A recent list of recommended varieties includes Daros I, Daros II, Eckendorfer Früflachs, Hohenheimer Blaublühend, and Mathis Edelflachs. Ernst Schilling, director Forschungsinstitut, Sorau, has published several technical articles on flax, including flax breeding, and has introduced the variety Sorau Feinflachs. Fr. Tobler, director Staatlichen Botanischen Garten, Dresden, has published several articles on fiber flax improvement and cultivation. G. Bredemann, director Botanische Staatsinstitut, Hamburg, has published in reference to fiber flax. Two recent books by German authors are important contributions to the flax literature. These are Der Flachs als Faser– und Ölpflanze by Tobler (*27*), published in 1928, and Der Flachs, as volume 1 of Technologie der Textilefasern, by Kind, Koenig, Müller, Schilling, and Steinbrinck (*14*), published in 1930. These excellent texts discuss fully the subjects of botany of the flax plant, flax improvement, flax diseases, and the tehcnical phases of flax-fiber production.

HUNGARY:

The Agricultural Experiment Station for Hemp and Flax Culture, Szeged, has carried on breeding work with flax and developed new strains of both fiber flax and seed flax. Ing. Rudolf Fleischmann, director, Plant Breeding Station, Kompolt, Hungary, has introduced the new strains Fleischmann no. 31 and nos. 179 and 188, and has published articles on the subject of flax improvement.

LITHUANIA:

D. Rudzinzkis, director of plant breeding, Lithuanian Agricultural Experiment Station, Dotnuva, has had long experience in the selection of fiber flax and recently has introduced the new variety Dotnuvos pluostiniai.

SWEDEN:

The Agricultural Experiment Station of Svalöf has recently introduced the fiber flax varieties Blenda and Herkules.

UNION OF SOCIALIST SOVIET REPUBLICS:

Perhaps the most extensive collection of flax varieties has been assembled by Vavilov (*29*), director, Institute of Applied Botany, Leningrad, who has made a systematic study of the flaxes of Europe, Asia, and Africa. The selection and breeding of flax varieties has been carried on extensively at the several agricultural experiment stations of the Union of Socialist Soviet Republics and by the Central Association of Flax and Hemp Growers. The flax-breeding work is coordinated in a general way, although different lines of flax improvement are carried on at each station. N. A. Diakonov has conducted the important fiber-flax selection at the Pskov Agricultural Experiment Station, and N. D. Matveive has charge of similar work at the Moscow Plant Breeding Station, where the fiber flax No. 8063 was developed. The earlier work is summarized in a publication, Methods of Flax and Hemp Breeding, published in 1929 by the Institute of Applied Botany, Leningrad. As mentioned earlier in this section, Dr. Vavilov has furnished the writer seed of many of his distinct geographical strains of flax, which have been grown for observation in the United States.

Superior Germ Plasm in Tobacco

By W. W. Garner, Principal Physiologist, H. A. Allard, Senior Physiologist, and E. E. Clayton, Senior Pathologist, Bureau of Plant Industry[1]

PLANT breeding has accomplished a great many extraordinary things, but in all modesty the tobacco breeder must confess at the outset that he is somewhat baffled by the old problem of how to give Americans a good 5-cent cigar. There are two difficulties in tobacco breeding that condition his work and that account for the present direction of his efforts.

The first difficulty is the fact that the thing of greatest importance in tobacco is quality. This is true to a considerable extent for other plant crops also, but with very few crops is quality as all-important as it is in the case of tobacco. Moreover, in the case of many other crops, quality can be measured, not easily, perhaps, but relatively easily. In wheat, for example, it depends to a large extent on the quantity of protein in the grain and the baking strength of the gluten, and these can be measured in one way or another.

The finer elements in the quality of tobacco cannot be measured. They depend mainly on two things—flavor and aroma. There are only two known devices capable of testing flavor and aroma, and they are not machines—the palate and the nose. This is the reason why, when so much else has been reduced to a mechanical basis, we still have to have coffee tasters, tea tasters, butter tasters, cheese tasters, and perfume experts. And even these are few and far between. They are born, not made.

The Present Work of the Tobacco Breeder and Possibilities for the Future

IN OTHER words, these elements in the quality of tobacco are extraordinarily subtle. Not only can they not be measured as yet; by the same token, they are not under the control of the plant breeder. Since he has no notion what factors are responsible for these qual-

[1] The authors are indebted to Harold H. Smith, Division of Tobacco and Plant Nutrition, Bureau of Plant Industry, for valuable assistance in preparing this survey.

ities, he cannot breed for them. The most he can say is that they fall in the class of quantitative factors—that is, the characteristics involved are not sharply divided off from one another, like black from white; they run through a range from the very weak to the very intense, something like a scale of musical notes. The inheritance of characteristics of this sort is always complicated, and it almost always depends on several or many factors acting together and having complex effects in combination.

The second difficulty in breeding is that these and other characteristics of tobacco are enormously influenced by soil and environment.

Every living organism is influenced by environment; it starts out with certain inherited potentialities, but whether they will be realized fully, or how they will be realized, depends on the environment. This is both especially noticeable and especially important in the case of tobacco. A certain tobacco grown in one region and on one kind of soil may be quite different when it is grown in another region on another kind of soil. So true is this that there may be very important differences between tobacco in one field and the same tobacco in the next field. Moreover, it is not known as yet just what accounts for these differences. Certain sections in Cuba, for example, grow the world's finest cigar filler. A farmer in one of these sections may produce a top-notch product; a neighboring farmer, using the same seed and the same cultural methods, and having apparently very similar soil, may be unable to produce anything but a comparatively low-grade leaf.

This is one of the reasons why tobacco growing pays such uneven returns. Seemingly unimportant differences in environment may make all the difference between a premium price and a very low price. The proportion of high-grade leaf in a crop, rather than the total yield, is likely to determine the value of the crop.

Every element in the environment of tobacco has a similar importance—use of fertilizers, cultural methods, and methods of harvesting and curing. Much may be done, through these methods, to change the character of the final product and to affect its quality for better or worse. Thus the growing of tobacco gives plenty of scope for good judgment and expertness.

What does all this mean to the plant breeder?

(1) Breeding new varities for improved quality of the finished product is not within the scope of his operations. This is not to say that it may not be at some time in the future. Even though quality is not definitely pinned down to certain genetic factors, it may prove possible to find observable traits that are associated with the more elusive characters, and to breed for these, thus getting at quality indirectly. Some leaf characteristics that influence quality can be observed and tested far more readily than taste and aroma—for example, tissue structure, elasticity, combustibility, and the character of the ash when smoked. Fortunately, there is no great pressure to breed for improved quality, since the varieties now in cultivation in the United States are reasonably satisfactory in both quality and yield.

(2) It is possible, however, to breed for other characteristics of great importance, especially to the grower. Size, shape, number, and spacing (length of internodes) of leaves; earliness in maturing; thickness, venation, color, and nicotine content of leaves; suckering habit, which affects production costs, since free-suckering plants are

more expensive to cultivate; and above all, disease resistance—all of these do come within the scope of breeding work. One of the fruitful projects has been the breeding of tobacco plants with a very high nicotine content, for use as a source of a valuable insecticide.

At present, most of the effort is concentrated on disease resistance, since there are several diseases that take a heavy toll in tobacco growing.

(3) But even in this work, the two stubborn facts—that quality is of prime importance, and that environmental influences have much to do with the character of the final product—must be engraved on the brain of the tobacco breeder so that he never forgets them. It may be quite possible to breed a plant resistant to a certain disease; but if, in the process, desirable qualities are lost or modified adversely, the new plant may be valueless, even though it is completely immune to the disease. Or again, the breeder may produce a plant that is satisfactory in the environment where the work is done, but unsatisfactory in the environment where that type of tobacco is commercially grown, or vice versa.

He must, then, constantly observe three precautions: (1) Use as breeding stock plants that, in addition to the other desired characteristics, have the necessary quality; (2) carry any new strains right through the entire process of curing and manufacturing to make sure that they will meet the test of quality; and (3) produce and test his new strains in a uniform environment as alike as possible to the one in which they are destined to be grown commercially.

This is the background and these are the chief limiting conditions in tobacco-breeding work. A good deal has been accomplished in this field. First, the work that is now in progress will be taken up, and then the development of present types and varieties, which came about as a result of environmental influences and 300 years of selection, will be traced.

THE TECHNIQUE OF BREEDING

The technique used in inbreeding and crossbreeding is not difficult but it requires close attention to details.

Owing to the size and simple structure of the flowers, the great number of seeds produced, and the readiness with which the flowers can be handled in the technique required for self-pollination and cross-pollination, tobacco is particularly well suited for breeding operations.

A single flower may produce from 4,000 to 8,000 seeds, and the entire flower cluster of a plant may yield a million seeds or more. The pollen itself is readily secured, and when carefully dried and stored in stoppered vials it will retain its active fecundating properties for several weeks, so that it can even be shipped long distances for use.

Under proper conditions of storage in cork-stoppered glass vials, the seeds will retain their viability for 10 to 15 years, or longer. The abundance of seeds produced by a single capsule makes it possible quickly to secure an experimental progeny numbered in the thousands. An ounce of cleaned seed contains about 300,000 individuals.

The tobacco flower (fig. 1) is white or colored. It is borne on a short stem and has a green calyx cut into five more or less pointed divisions known as the calyx lobes. From the calyx emerges the corolla tube, which in some species of tobacco, as in *Nicotiana longiflora*, is very long and slender; in *N. rustica*, it is short and swollen. The corolla tube usually expands at the top into a colored limb,

with five parts or lobes. Within the tube, the stamens and pistils are borne. These are the essential sex organs of the flower.

The pistil is the female element, and in the tobacco it comprises three distinct structures. Its swollen base, the ovary, contains the ovules closely arranged upon a fleshy axis called the placenta, which attaches them to the ovary. At maturity the ovary is greatly enlarged and becomes the seed pod, bearing the ripened seeds. From the top of the ovary, a long, slender stal or style rises. This ends in a blunt, more or less two-lobed swelling, the stigma, near the opening of the corolla tube. When the flower opens, this stigma is usually more or less glutinous or sticky so that any pollen reaching it will adhere.

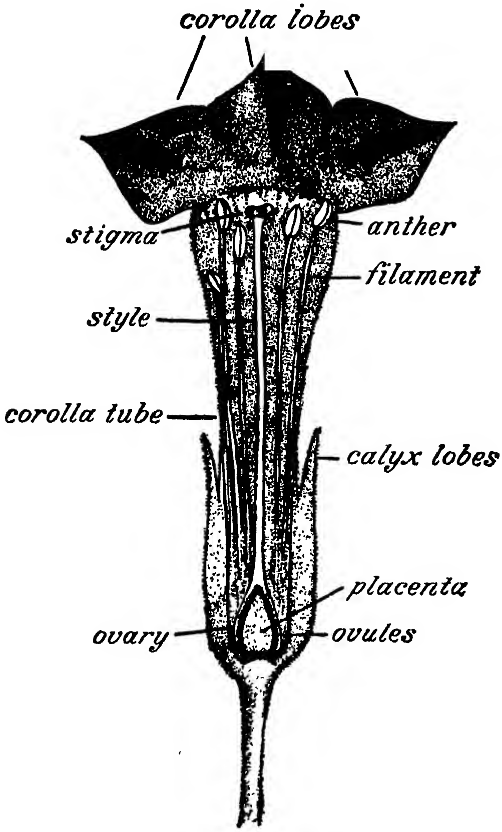

FIGURE 1.—Longitudinal section through a tobacco flower of the White Burley variety, showing the corolla, calyx, stamens, pistil, and ovules borne upon a fleshy axial placenta (drawn by H. A. Allard).

Around the stigma and its supporting stalk or style, five separate stamens are closely arranged. Each of these in turn consists of a slender stalk or filament bearing an enlarged saclike portion at the top known as the anther. The anther consists of cells which open lengthwise by a slit when they are mature, to liberate the fertilizing pollen. This falls on the stigma, which they surround more or less closely. The filaments of the anthers are attached to the corolla tube. The anthers are the male structures of the flowers.

The tobacco flower is so constructed that the anthers normally pollinate the stigma of the same flower—that is, the flower is self-fertilized. However, pollen from other flowers, other plants, or even other races, varieties, or species of tobacco growing in the vicinity may fall on the stigma or be carried to it by insects or other pollinating agencies. To be absolutely sure that the flowers are self-fertilized, therefore, the breeder has to keep out any foreign pollen by covering the blossoms with bags, screening, etc.

Bagging of the seed heads is also necessary to insure close fertilization. For this purpose, strong paper bags of the satchel-bottom type, capable of resisting wind and rain throughout the season, are recommended. For large, untrimmed seed heads, bags of 16- to 20-pound volume are best. If the seed heads are trimmed to 25 or 30 capsules, bags of smaller size may be used.

The first flowers to open usually develop the largest capsules and seeds. The outside flowers of the seed head, arising late in the season when the vigor of the plant is waning, are likely to be smallest. Tests have shown that trimming the seed head to 25 to 30 capsules may result in heavier and better seed. If the maximum amount of seed is desired from a plant, however, untrimmed seed heads should be bagged.

When a plant is bagged, seed pods and blossoms that have already opened should be removed, as foreign pollen may have been introduced by insects. It is exceedingly important to inspect the flower head very carefully to remove all caterpillars, since these will feed on the flowers and capsules in the bags. Lead arsenate dust or combinations with paris green may also be used. The bag is then placed over the flower head and its lower edge is crumpled snugly around the stem and tied (fig. 2).

FIGURE 2.—Placing paper bag over flower head after it has been trimmed and the upper leaves of the plant have been removed. The mouth of the bag is drawn about the stem and securely tied in place. By this means cross-pollination is effectively prevented.

When large quantities of selfed seed are secured, a superior grade of seed can be obtained by separation of the heavy from the lighter seed and chaff, using a cleaning or blowing device.

Making Crosses

This description applies when flowers are to be self-fertilized. The operation of artificial crossing or hybridization requires other special manipulations. When a desirable plant is selected as the mother of the seed, all open blossoms and seed pods are carefully cut away, and only closed buds, those chosen to receive pollen, are left. These should be the buds that will open their corollas the next day; the large size and the pink color of the tip will readily show which buds are about ready to open. Since self-pollination must be avoided in this case, these flowers to receive foreign pollen must be emasculated; that is, all

the anthers or male organs must be removed. This is done by slitting the corolla open with a sharp knife or scalpel and taking the anthers out with a pair of forceps. The hands, scalpel, and forceps should be sterilized with alcohol before the buds are opened, especially if a series of emasculations are being made on different types, to prevent possible contamination with foreign pollen.

It is very important that no bud be saved for crossing if it is found that any of the anthers have opened prematurely, as sometimes happens, so that pollen might already have gotten on the stigma. And when the flower head is finally ready for bagging, only those flowers that have been emasculated should be ready to open the next day. Any others that look as though they might open should be removed.

The treatment of the flowers chosen to serve as the male parent by furnishing pollen is a simple matter, since the flower head is merely bagged after all blossoms that had opened previously are removed.

The morning after emasculation, when the stigmas are normally sticky and in a receptive condition, the transfer of pollen is made from the male flowers. To do this, the male flower may be picked from the plant and applied to the stigma of the emasculated flower so that an open anther cell will rub its pollen upon the sticky surface, or all the anthers may be thus used. This male flower may then be thrown away and another male flower removed to pollinate other blossoms. Once pollination has been accomplished, the individual flower stem should receive a small tag giving data as to variety, individual, male parent, etc. These hand-pollinated flowers are then covered with bags again. It is important to see that all buds on the mother plant that give evidence of opening within the next few days are cut away lest their pollen contaminate the cross before final fertilization with the selected foreign pollen has been completed.

It is an advantage to make crosses on the first blossoms of the flower head to open, since at this time flowering is in its fullest vigor, and there is less chance that blossoms will be shed or drop off than there is later. The pollination of decidedly immature blossoms that will not open for several days should not be attempted.

The transfer of pollen can be done with a small brush, but if different crosses are made, there is danger of contamination from adhering pollen grains that cannot be seen with the naked eye owing to their microscopic size.

If crosses are made between compatible strains or varieties, true fertilization of the ovules soon imparts a stimulus to the ovary, which quickly enlarges and produces fertile seed. In crosses between some species, the foreign pollen may be almost or quite sterile for that flower, and the capsule will grow little or not at all, and perhaps ultimately fall off. The pollen of other species, even though it is sterile or nearly so as far as fertilizing the ovules is concerned, may yet lead to a fairly normal growth of the ovary itself, though few or no viable seed are produced. This is a growth influence of the pollen, distinct from fertilization of the ovules, and it is known as parthenocarpy.[2]

Because of the small size of tobacco seed, it is more difficult than might be supposed to avoid occasional accidental mixing of seeds in handling and planting operations. A few foreign seeds, or even one, might ruin a whole genetic experiment. In cleaning the seed, therefore, care is required to insure that no individuals remain on the screen

[2] From the Greek root, partheno, virgin, or without being fertilized.

or in the blowing apparatus when a second lot is introduced. In propagating, the seed may be planted in pots or flats in the greenhouse, or, if seedlings are required in large numbers, planting can be made in the usual type of cold frame; but regardless of the method of planting it is highly important that adequate safeguards be employed to prevent transfer of seeds from one planting to another by insects, wind, or other means.

Stress has been laid on the marked effects of environment on growth habit, size characteristics, and the commercial quality of tobacco, and on the importance of making sure that the material for study is grown under a uniform environment. It is essential also that such cultural details as spacing of the plants in the field, the height of topping if this operation is carried out, the stage of maturity at which the plant or individual leaf is harvested, and the method and conditions of curing be carefully standardized. Control of these environmental and cultural factors cannot be disregarded if dependable results are to be obtained.

AVAILABLE BREEDING STOCKS

One other point should be mentioned in connection with the technique of breeding operations—maintaining stocks of viable seed of all varieties for use at any time in breeding experiments. At the present time, collections of seed of numerous strains representing the standard varieties, and including of course the new productions, are maintained in the Bureau of Plant Industry and some of the State agricultural experiment stations. Many of these are pure lines. There are also limited collections of foreign varieties, and these are being extended, especially in the direction of increasing stocks for breeding for disease resistance and other special purposes. A partial list of varieties and strains covered in these collections, and their points of special value, is given in table 3 (p. 829). Because of the vast number of strains in use, it would obviously be a huge undertaking to bring together and maintain seeds of all of them in a single collection.

As collections of disease-resistant material are assembled and tested, it is extremely important that provision be made to keep all of this material available for future study. Varieties resistant to disease in varying degree have been reported by previous investigators, and in some cases it is now impossible to get authentic seed of these strains. In breeding work, it is not practicable to consider at any one time all characters of possible value. Diseases at present considered minor may later assume importance, and new ones may appaer, just as did wildfire and more recently mildew. Further, as improved varieties resistant to disease are developed, authentic sources of seed must be established, because it may be expected that resistant and susceptible strains will be identical in appearance, and in the hands of growers mixtures are likely to occur. It appears that these needs can be met only by continued close cooperation between State and Federal authorities.

INVESTIGATIONS IN PROGRESS ON DISEASE RESISTANCE

The increasingly heavy losses from disease in recent years make breeding for greater disease resistance imperative, and major attention at present is being given to this problem. Earlier studies indicated clearly both the possibilities and the complexity of the problems.

Partly in cooperation and partly on an independent basis, the Bureau of Plant Industry and most of the important tobacco-growing States are conducting investigations in the production of desirable disease-resistant varieties. These projects are listed in table 4. Cooperative studies are now under way between the Bureau of Plant Industry and the States of Connecticut, Massachusetts, Wisconsin, Maryland, Tennessee, West Virginia, North Carolina, South Carolina, and Georgia; and as the work is not yet fully organized, it is expected that additional cooperative arrangements will be made in the near future. The objective of the program here briefly outlined is (1) to provide a sound fundamental background for the entire problem, and (2) with the aid of this information, to carry forward specific disease studies applicable to limited areas.

Nicotiana tabacum is a most variable species, and innumerable types and varieties are grown in all parts of the world. The first undertaking has been to secure adequate seed material, and to study the occurrence of disease resistance in this material. Certain varieties are known to be resistant to certain diseases, but whether these are the only resistant types, or the best, is not known. So far, in addition to domestic varieties, 140 foreign collections distributed among the following countries have been studied: Africa, Argentina, Brazil, British Guiana, Dutch Guiana, Colombia, China, Cuba, Honduras, Java, Japan, Mexico, Puerto Rico, Peru, Philippine Islands, Union of Soviet Socialist Republics, Sumatra, Turkey, Uruguay, and Venezuela. Other foreign collections are constantly being received and included in these studies. In conducting this work it has been necessary (1) to develop methods for detecting and measuring disease resistance, the latter being especially important, since in few instances does resistance approach immunity, so that it is necessary to determine which of a number of varieties possesses the maximum degree of resistance; (2) to test each collection separately for each disease; and (3) to investigate the mode of inheritance of this resistance.

In the following discussion, (1) and (2) will be treated together. As promising lines of resistant plants have been detected by means of the laboratory and greenhouse studies, they have been planted in field plots in the several areas where the diseases are most serious. These field tests are depended on to furnish information as to the value of different degrees of resistance under field and seedbed conditions, and also to supply information as to the morphological and quality characteristics of new varieties. Studies on the occurrence of disease resistance are by no means completed and conclusions as to the best parent stocks for the breeding of new types more resistant to disease than our present varieties may be materially modified by work in progress. It was only a few years ago that discussions of tobacco breeding for disease resistance were practically limited to black root rot. If this is kept in mind, it will be evident in what follows that the possibilities have been rapidly and strikingly extended.

Occurrence of Disease Resistance and Methods of Testing

Granville wilt (*Bacterium solanacearum*) is a bacterial disease—the brown rot that also affects the potato, tomato, eggplant, and pepper. Workers in the Netherlands studied resistance by inoculating plants in the stems with bits of diseased tissue. However, under natural conditions this disease invades the plants by way of the roots, as a

result of soil-borne infection. Comparison of soil and stem inoculation shows that several varieties are resistant to soil inoculation and susceptible to stem inoculation. Resistance to soil inoculation indicates resistance to invasion, that is, morphological resistance. Some varieties, however, resist the development of the disease even after the organisms are inside the plants. This resistance is referred to as physiological. Resistance to wilt is modified by age, increasing as the plants become older. The development of the disease is also favored by rapid plant growth and high temperatures (80° F. and above).

All domestic varieties tried are highly susceptible to wilt, but this is not the case with foreign varieties tested, about one-third of which

FIGURE 3.—Resistance to Granville wilt. The row in the foreground was planted with Cash, a standard flue-cured strain, and the row to the left with a resistant selection from a foreign variety, 79A. At the time photographed, 15 percent of the plants had been killed in the resistant row and 92 percent in the Cash row.

show slight to moderate resistance. The most resistant strain obtained so far is a selection, No. 79A, from an unknown variety secured in Java. This selection was tested in the field in 1935 under severe wilt conditions and 25 to 30 percent of the plants were dead at the end of the season, while check plantings of a susceptible domestic type were 90 to 95 percent killed. Figure 3 shows the ability of the resistant strain to produce a fair crop under conditions such that the check planting of Cash was almost a complete loss. Strain No. 79A is not a flue-cured type and does not approach immunity in its resistance.

Mildew or blue mold (*Peronospora tabacina*) is a disease due to the type of fungus known as a downy mildew. Satisfactory inoculation is no problem with this disease, because once the organism is introduced into a greenhouse or plant bed, and favorable conditions

prevail, the fungus naturally spreads so that every plant is infected. The disease is very dependent on environmental conditions, and studies on resistance can be conducted only when temperatures between 55° and 70° F. prevail, in combination with high humidity. Resistance increases with age of plants and rapid-growing plants are most susceptible.

All domestic varieties are completely susceptible as far as known, but a few foreign sorts are slighly to moderately resistant. The most resistant of these is No. 57, a variety obtained from Argentina under the name Chileno Correntino. This variety gives a fair stand of plants under conditions such that susceptible sorts are completely destroyed. Using older plants, leaf injury is greatly reduced with the resistant type, and in one seedbed test the susceptible variety showed much stem injury while the stems of No. 57 remained clean. A higher degree of resistance, however, is very desirable.

Mosaic. The first virus disease ever transmitted experimentally from a diseased to a healthy plant was tobacco mosaic. It is the one disease studied where, within reasonable limits, the method of inoculation, age, condition of plants, and environment make little difference in the results. However, in studying the progeny from crosses between resistant and susceptible types, simple inoculation and observation is inadequate, because plants showing different degrees of resistance are obtained. By inoculating healthy plants with the juice from each mosaic-resistant plant, however, it is possible to differentiate clearly between (1) resistant plants carrying the virus and showing faint leaf symptoms and (2) plants apparently free from virus and showing no leaf symptoms.

All domestic varieties are susceptible, and the same is true of all foreign collections tested excepting Ambalema. This variety is highly resistant to ordinary tobacco mosaic, as reported by Nolla and Roque (1933). Figure 4 shows an Ambalema plant growing beside a plant of Maryland Broadleaf, both having been inoculated with mosaic. The Ambalema variety is being extensively used in the breeding work now in progress for control of mosaic.

Wildfire (*Bacterium tabacum*). In contrast to mosaic, this disease, due to bacteria, is one of the most difficult to study with respect to resistance. Seedling inoculations have been much used, but our results with seedlings were not comparable with those obtained from mature plants of the same varieties under field conditions. Hence, since most wildfire damage occurs in the field, it is necessary to work with field-grown plants. In evaluating wildfire resistance, it is further necessary to study separately (1) resistance to infection and spread of the bacteria through normal leaf tissues, and (2) resistance of leaf tissues to water-soaking. It is water-soaking that is responsible for the development of the destructive, epidemic type of wildfire. To study resistance to water-soaking, leaves of the same maturity grown under uniform field conditions are exposed to a uniform water spray and the time required to produce water-soaking is recorded for both upper and lower leaf surfaces. Results indicate that differences in susceptibility to water-soaking dependent on both cultural and heritable factors can readily be measured by this method.

Contrary to general belief, most domestic varieties are moderately resistant to wildfire under field conditions. On the other hand, about two-thirds of the foreign varieties are highly susceptible. Further study will be required before conclusions can be arrived at

regarding the possibility of increasing the wildfire resistance of our present varieties. So far no type immune to wildfire has been discovered.

Blackfire (*Bacterium angulatum*). The same complicated situation indicated for wildfire also holds true for blackfire or angular leaf spot, another bacterial disease, and similar methods are being used in studying resistance. Most domestic varieties of tobacco are moderately resistant.

Studies in measurement of disease resistance are in progress with root knot (*Heterodera marioni*), a disease caused by a minute eelworm

FIGURE 4.—Mosaic resistance: *A*, Maryland Broadleaf; *B*, Ambalema. Both plants were inoculated with mosaic and the severe dwarfing produced by the disease is noticeable with the Maryland Broadleaf; the Ambalema plant did not become infected.

or nematode, and with the following fungus diseases: Black root rot (*Thielavia basicola*), stem rot (*Sclerotium rolfsii*) and black shank (*Phytopthora nicotianae*).

Black root rot. As reported by Johnson (1930), domestic varieties vary from highly susceptible (Judy Pride Burley) to moderately resistant (certain cigar types and resistant burleys), and foreign varieties range from highly susceptible to practically immune (Xanthi and other Turkish types). Figure 5 shows the marked difference in growth on diseased soil of susceptible and moderately resistant

varieties. In breeding projects now under way for root rot resistance, Johnson Resistant Standup Burley, resistant cigar leaf varieties, and Turkish varieties are being used.

Root knot. Extensive tests so far indicate that all domestic varieties tried are susceptible with the exception of a strain of Orinoco known as Faucette Special, which shows moderate resistance. Since this is a flue-cured sort adapted to the area where root knot is most severe, it may prove of considerable value. One foreign variety, White Honduras, is also moderately resistant. There is great need for a tobacco that is highly resistant to root knot.

Black shank. Reports by Tisdale (*11*)[3] that as far as known all domestic varieties excepting the Big Cuban and ordinary Cuban are susceptible have been confirmed by further test. Studies of foreign collections have not yet been completed. No. 301, the resistant

FIGURE 5.—The growth of susceptible and moderately resistant strains of tobacco on soil infested with black root rot. No. 22, Connecticut Broadleaf; No. 23, selection from a cross between the susceptible Maryland Broadleaf and Johnson Resistant Burley; No. 24, Maryland Broadleaf. Nos. 25 and 26, other resistant lines.

cigar-leaf type developed by Tisdale in Florida, is highly resistant to black shank and is being used as the resistant parent in breeding work now in progress. Figure 6 illustrates the ability of No. 301 to produce a healthy crop of tobacco under conditions such that the susceptible variety was a complete failure.

Inheritance of Disease Resistance

From the genetic standpoint, resistance to disease has been investigated by Johnson (*9*) in the case of *Thielavia* root rot, and by Tisdale (*11*) in black shank (*Phytophthora*). Unfortunately, in these diseases resistance appears to be quantitative in nature and controlled by multiple factors. It behaves genetically in a manner similar to that

[3] Italic numbers in parentheses refer to selected references, p. 828.

observed in studies of size characters. The studies, however, are being continued with the different diseases, and they are being facilitated by the use of definite, controlled methods for measuring resistance. Thus, the method previously discussed for measuring resistance of leaves to water-soaking in the wildfire and blackfire studies gives data capable of careful analysis. Close comparisons of this sort are very difficult to secure under natural field conditions. Again, uniform procedure in inoculating plant populations avoids the complications presented in the field by the presence of susceptible individuals that escape natural infection.[4]

The present studies on inheritance of resistance have progressed far enough to lead to definite conclusion only in the case of mosaic.

FIGURE 6.—Black shank susceptible and resistant varieties growing (under artificial shade) on infested soil. The diseased row in center is the susceptible Connecticut Round Tip; the healthy rows on either side are the resistant 301. (Courtesy Florida Agricultural Experiment Station.)

Here counts on a large F_2 population from a Maryland Broadleaf-Ambalema cross indicate that mosaic resistance is dependent on three pairs of recessive factors. This most favorable circumstance, if confirmed by further work under way, makes possible back-crossing of F_2 plants, with the certainty that these will be homozygous for resistance.

Some Essentials for Further Development of the Disease-Resistance Program

Breeding for disease resistance offers a promising means of effectively combating some of our most destructive diseases, and is receiving more and more attention. It is worth while, then, to point out briefly some of the major obstacles to be overcome.

[4] See Introduction, p. 129, for discussion of disease inoculation in breeding work.

First and most obvious is the need for stocks more highly resistant. The mosaic-resistant Ambalema probably approaches most nearly to the ideal sought, as it is practically immune to common mosaic and the number of factors involved is small enough to permit genetic analysis. It is doubtful whether this satisfactory situation exists with any other resistant stocks now available. To aid in meeting this need, the Bureau of Plant Industry is at present collecting material in Mexico, Central America, and South America—regions that are the native home of the species and the centers where the greatest diversity of types is to be found.

A second need that has been emphasized by results from previous work, and has been mentioned earlier in this section, is the need for increased attention to quality. Resistant types have been selected chiefly on the basis of visible characters. Sometimes they looked like the desired type but were actually quite different in quality. At present it must be accepted that it is impossible to select for quality in the growing crop, and repeated back-crossing to the parent that possesses the desired quality is the only method that gives promise of solving this problem. The fact that resistant types lacking even slightly in the desired quality will not be commercially acceptable probably constitutes the greatest single obstacle to the success of the breeding program.

Another important thing that is at present being largely ignored by tobacco breeders is the need to take into account the reaction of parent stocks to all diseases and not merely to the single disease under consideration. This omission may have serious consequences. Thus it has not been recognized that certain foreign types highly resistant to black root rot are also highly susceptible to wildfire, to which most domestic varieties are moderately resistant. At present wildfire occurs in serious form only in limited areas, but past history indicates that the disease is capable of developing in many other areas, and consequently introduction of varieties highly susceptible to it would not be safe. Tests during 1935 have shown that one recently developed variety resistant to root rot is distinctly less resistant to wildfire than the original standard type. The complexity of this problem may be further illustrated by table 1, which shows the disease resistance of two varieties, Cash and No. 79A, now being used in the production of a wilt-resistant flue-cured type.

TABLE 1.— *Resistance of Cash and No. 79A to different diseases*

Variety	Wilt	Wildfire	Blackfire	Black root rot	Fusarium wilt	Mosaic	Black shank
Cash	Slight	Moderate	Moderate	Slight	Moderate	None	None.
79A	Moderate	Slight	do.	Moderate	Slight	do	Do.

Study of the above analysis shows that the F_2 generation from this cross, which is now being tested, might, if studied for resistance to wilt only, give wilt resistance in combination with susceptibility or moderate resistance to black root rot, Fusarium wilt, and wildfire. On the other hand, by careful testing it might be possible to continue with lines possessing the maximum of resistance to all four diseases. The fact that at the present time wilt is the only disease of the four

that is a serious problem in the area concerned would by no means justify ignoring the other diseases, since all are potential hazards.

A list of projects now under way on the breeding of disease-resistant varieties of tobacco is given in table 4 (p. 830), and a list of Department of Agriculture and State experiment-station workers on page 830.

In considering the future development of this work, it is to be remembered that losses from disease have increased rapidly in recent years, and, since our standard types are highly susceptible to most of the diseases, there is a pressing need for introducing resistance, without sacrificing quality, for practically every type of tobacco and every producing area. General estimates of the losses from tobacco diseases are not available, but two specific examples may be cited. In North Carolina alone root knot and wilt cost the growers at least $5,000,000 annually. In Pennsylvania wildfire reduces the value of the crop in some years as much as 50 percent. The magnitude of the breeder's task needs no emphasis.

Up to now, investigators have attempted to develop varieties resistant to individual diseases, but the logic of combining in one variety resistance to more than one disease cannot be escaped and must be met in the future. Moreover, since in research in disease resistance we are dealing not with isolated needs, but rather with a long-time major program for varietal improvement, it is obviously desirable to coordinate future investigations closely. Much of the actual work must be carried forward in local areas because only under these conditions can progenies be studied for both disease resistance and quality—and improved resistance at the expense of quality is a barren achievement. Coordination of these individual projects, however, will make possible the use of only the most desirable parent stocks, and concentration on the best methods. Finally, it is suggested that in the future, new varieties should be subjected to most rigid tests before they are released, since only in this way can the desire of the grower for protection against disease and that of the manufacturer for stable quality be adequately safeguarded.

OTHER INVESTIGATIONS AND PROBLEMS IN TOBACCO BREEDING

Although the work of the tobacco breeder is largely concerned with disease resistance for the present, this does not by any means tell the whole story. A number of other investigations and experiments will be summarized before discussing the outlook for the future.

The Kentucky Agricultural Experiment Station is endeavoring to develop a strain of White Burley of improved suckering habit by crossing root-rot resistant Burleys with the variety known as One Sucker, the objective sought being to reduce somewhat the cost of labor in growing the crop. When tobacco is topped or disbudded, as is usually done in practice, shoots or suckers develop in the axils of the leaves and these must be removed from time to time as they appear in order that the leaves may attain full development.

At the Florida Agricultural Experiment Station, investigations are in progress to determine what elements of quality, if any, are linked with resistance to the black shank disease. Studies also are being made on the inheritance of leaf size and number of leaves and on the number of factors involved in expression of the disease-resistant character.

A genetic study of inheritance of resistance to *Thielavia basicola* is in progress at the West Virginia Agricultural Experiment Station.

In cooperation with the Massachusetts and Connecticut Agricultural Experiment Stations, the Bureau of Plant Industry is seeking to standardize the Havana Seed type of leaf in the Connecticut Valley as far as this may be possible. The effort is to produce one or two strains meeting the requirements of both farmer and manufacturer in all essentials, including root rot resistance, yield, and quality, when grown on either infested or on healthy soil.

A good deal of experimental work has been done in breeding for nicotine content, both high and low; and results in the case of extremely high nicotine content promise to be of great value in the development of cheaper nicotine sprays to combat insect pests in farming operations.

THE *increasingly heavy losses from disease in recent years make breeding for greater disease resistance imperative, and major attention is at present being given to this problem, The objective of the program is to provide a sound fundamental background for the entire problem, and to carry forward specific disease studies applicable to limited areas. In conducting this work it has been necessary to develop methods for detecting and measuring disease resistance; to test each collection separately for each disease; and to investigate the mode of inheritance of this resistance. Only a few years ago, discussions of tobacco breeding for disease resistance were practically limited to black rot. If this be kept in mind, it will be evident that the possibilities have been rapidly and strikingly extended.*

Low Nicotine Content

Nicotine is the characteristic alkaloid of tobacco to which it owes its habit-forming properties, and relative nicotine content affords the best measure of the strength of a tobacco product. The quantity of alkaloid in the tobacco leaf is influenced by many factors, of which heredity is one of the more important. As far as is known, the relative content of nicotine is not definitely correlated with any important element of quality in the leaf other than strength, at least within rather wide limits. Because of the marked effects of environment and cultural practices, the nicotine content of tobacco usually depends more on the commercial type and the grade of the leaf than on the variety or strain of seed used. The dark fire-cured and dark air-cured

types are high in nicotine, and the chewing grades of these and other types as a class contain more nicotine than the corresponding smoking grades.

Among smokers as a whole, there are some who prefer strong cigars, cigarettes, or smoking mixtures, but apparently the majority favor mild products, and many desire products with a very low content of alkaloid. The problem of reducing the nicotine content of manufactured tobacco products, both by partial removal of the alkaloid from the cured leaf or the finished product and by developing low-nicotine varieties or strains, has recently attracted considerable attention. On the other hand, since tobacco is used chiefly because it contains nicotine, there would seem to be no purpose in producing a tobacco containing only negligible quantities of alkaloid except for use in blending with strong types of leaf.

As early as 1907–9 (*4*) two strains of the Cuban variety characterized by a low nicotine content were obtained by selection in the Bureau of Plant Industry. As grown in east Texas in 1909, 30 individuals of one strain showed a range in percentage content of nicotine from 0.50 to 0.18, with a mean of 0.34, and the corresponding values of the second strain were 0.72, 0.36, and 0.50—whereas other control strains showed values three to five times as high. The low-nicotine strains have been grown repeatedly under various conditious and invariably have shown a greatly reduced content of nicotine as compared with ordinary strains of Cuban and other varieties. These strains have not been grown commercially for the reason that the Cuban variety is a poor yielder and is not used in this country for production of cigar filler.

Recently strains of the Cuban tobacco containing an exceedingly low content of nicotine as well as cigarette strains moderately low in nicotine also have been produced at the Kaiser Wilhelm Institute for Breeding Research at Müncheberg, Germany. It was found that inheritance of the low-nicotine characteristic is remarkably constant, only about 1 percent of the individuals in a population of 4,000 having a high content of nicotine. These strains were obtained by selection based on a rapid method for determining in the field the approximate content of nicotine in a very larger number of individuals.

In the Bureau of Plant Industry, United States Department of Agriculture, work is in progress in cooperation with the Pennsylvania Agricultural Experiment Station in developing low-nicotine strains of the cigar-filler type by hybridization of local varieties with a low-nicotine strain of Cuban, and in cooperation with the Maryland Agricultural Experiment Station in development of similar strains of the Maryland cigarette type by selection in local varieties. Similar work is under way at the Kentucky Agricultural Experiment Station in the production of a low-nicotine strain of White Burley by means of crosses of Burley with a low-nicotine sort obtained from Baur in Germany.

Production of strains of tobacco with an extremely low nicotine content is entirely feasible. But according to present commercial standards for cigar leaf, nicotine content is not directly taken into account in judging quality. Before strains very low in nicotine could be commercially useful, manufacturers would have to develop a special market for new brands of mild tobacco products.

High Nicotine Content

High nicotine content is another story. Nicotine has long been a valuable insecticide, and it is used in large quantities for control of certain insect pests of plants, particularly the aphis, and for control of mange or scab on sheep and cattle and certain parasites on poultry. The present supply is obtained almost exclusively from tobacco stems and low-grade leaf. It appears that the retail price is an important limiting factor in the use of nicotine, and recently there has been considerable interest in the possibility of growing high-nicotine tobaccos for direct use as raw material for extraction purposes. Although the large-leaf varieties of ordinary tobacco, *Nicotiana tabacum*, will produce a high tonnage of dry matter, the content of nicotine is relatively low. Another species, *N. rustica*, produces a lower tonnage of dry matter but has a high percentage content of nicotine (fig. 7). This species suckers badly, which adds materially to the cost of production.

FIGURE 7.—Brasilia variety of *Nicotiana rustica*. This is one of the largest sorts of *rustica* and produces a relatively high yield of nicotine. Brasilia appears to be the most promising *rustica* now available for production of tobacco for nicotine extraction purposes.

There are many varieties of *N. rustica* which differ greatly in size and to a lesser extent in content of nicotine. From a comparison of a large number of forms from various parts of the world, it has been found that a large-leaf variety known as Brasilia, seed of which was obtained some years ago from Italy, perhaps is the most promising from the standpoint of output of nicotine per acre. With this form, yields of 150 pounds of nicotine per acre have been obtained under favorable conditions, and in exceptional cases the yield has approximated 200 pounds. This variety, in common with all others tried, possesses undesirable habits of growth, especially with respect to suckering. The goal sought in the work with *N. rustica* has been an average yield approximating 200 pounds or somewhat more per acre under conditions that will avoid high production costs.

Because of practical difficulties, particularly that of standardizing their strength and their rapid deterioration, home making of sprays is a rather complex problem. In any case, the problems in economically growing the raw material remain essentially the same as for commercial extraction purposes. The Bureau of Plant Industry cooperating with the Pennsylvania Agricultural Experiment Station is endeavoring, through crosses between varieties of *N. rustica* and crosses of this species with ordinary tobacco and other species, to obtain new forms capable of producing a high acre yield of nicotine and having desirable growth habits, especially with respect to suckering.

THE OUTLOOK FOR THE FUTURE

For the immediate future, it appears that perhaps one of the more promising courses for the breeder to take would be to limit his efforts largely to increasing the percentage of high-grade leaf in the crop without modifying quality characteristics in the present varieties, and with only incidental attention to total yield. In the three major cigarette types of leaf, burley, flue-cured, and Maryland, and in the cigar-wrapper and binder types, probably the best opportunity for achieving this objective lies in well-directed efforts toward increasing the number of desirable leaves on the individual plant. As will be pointed out later, significant changes in this direction already have occurred, as illustrated by the replacement of the old broadleaf, drooping sorts of White Burley by the so-called stand-up sorts, the latter yielding an increased percentage of high-quality cigarette leaf. Increase in number of leaves per plant usually is associated with a slight reduction in leaf size and a more erect growth habit. Increasing the number of leaves per plant tends to reduce the proportion of "tops," which for the commercial types mentioned do not yield leaf of the grades used for cigarettes or cigar wrapper or binder.

Solution of these immediate problems, as well as that of obtaining satisfactory disease-resistant strains and varieties—and, in fact, the great majority of problems in varietal improvement—is subject to difficulties and limitations, some of which have been discussed. The importance of these limitations should not be overlooked. With respect to hybridization, it is the general consensus of opinion among those who have had the most experience, including in particular the Netherland East Indies investigators in this field (*12*), that anything in the way of promiscuous crossing of sorts differing widely in genetic composition will ordinarily be hardly more than a waste of effort from a practical standpoint. When hybridization is necessary, this should be limited as far as possible to local varieties or strains that are closely related genetically.

Practically all the variations in desirable characteristics of tobacco, from the standpoint of both the farmer and the manufacturer, are of a quantitative rather than a qualitative nature so far as inheritance is concerned. They are governed by a relatively complex genetic mechanism involving many Mendelian factors. It is difficult to eliminate or control the subtle influences of environment and cultural practices on the important properties of the leaf, especially in dealing with complex crosses. Moreover, as already pointed out, quality cannot be judged until the leaf has been carried through all the processes required to fit it for manufacture. Without necessary precautions in this direction, even continued selection within the variety is not without its dangers. Netherland East Indies investigators have found that different strains may be identical in visible characteristics and constant in their progenies but different in quality characters not recognizable in the field. Again, even in crosses between closely related pure lines, these investigators found that selfing for about 8 generations was required to obtain uniformity in leaf shape, while apparently about 20 generations would be necessary to secure uniformity in quality.

Despite the serious difficulties involved, the situation is not hopeless. The great genetic variability existing in *Nicotiana tabacum* affords a wealth of material for securing new combinations in dealing with the problems of satisfactory yield, quality, and disease resistance. Obviously the smaller the number of gene differences involved in a cross, the simpler will be the task of securing the desired recombination in a superior product. Progress will be facilitated, of course, by growing the experimental material in large numbers.

Backcrossing combined with selfing and selection is an important aid in obtaining the desired recombinations of multiple factors. Having obtained the F_1 of a desirable cross, ordinarily the procedure is to backcross separately to each parent and in each case to select especially for desirable characters of the nonrecurring parent in each subsequent generation. Before the backcrosses have departed too far from the respective nonrecurring parent with regard to its desirable characters, they should be selfed for several generations, the selection being continued as before. By crossing the two approximately purebreeding lines ultimately obtained, each largely like the parent employed in backcrossing but also containing desirable characters of the other parent, and selfing the F_1 and later generations, it may be possible to secure the desired combination of characters in a pure breeding line. Time may be saved by simultaneously carrying through several parallel series. With a better understanding of the genetics of tobacco, it may ultimately be possible, as previously suggested, to simplify the problem of selection for quality by utilizing such correlations as may be found to exist between visible growth habit and structure and the less tangible properties influencing quality.

Since doubling the chromosome numbers is known to produce more vigorous plants with larger leaves in some of the Solanaceae, this appears to furnish a possible means of improvement, especially in yield; and when no new genes are introduced in the doubling process, quality might well be maintained. Several methods other than hybridization are available for effecting chromosome doubling—including X-ray treatment, centrifuging, and temperature treatment of maturing germ cells.

Although only a limited number of spontaneous mutations have been reported in tobacco, it seems quite possible that through systematic search mutations of the less obvious type could be isolated which would represent significant improvement in yield or in quality. It has been recently suggested that artificially induced mutations such as may be obtained by X-raying may furnish new strains of considerable value, especially since in most cases the new form differs in only a single factor and therefore soon becomes constant.

Finally, straight selection as a means of improvement should not be overlooked. To a limited extent growers practice selection, but observation shows that in the main considerable variability exists in the many sorts of each variety in cultivation. If the breeder has clearly in mind the most desirable growth habit and size characteristics for a given variety and commercial leaf type, selection toward the ideal form presents no special problems. However, it must be stressed again that all lines developed should be systematically checked for quality after the leaf has been properly cured and processed.

The Story of the Development of the Present-Day Varieties of Tobacco

LIKE many other plant crops, tobacco is divided into distinct classes or groups, each of which has a different use. These divisions have come about during three centuries of cultivation of the plant and they are as basic in breeding work as they are in production, commerce, and manufacture. In the discussion so far, it seemed best to concentrate on present projects and future possibilities in breeding; but back of this lies much previous work, including the selection practiced by generations of growers and the more recent breeding for improvement by the experiment stations and the Department of Agriculture. In order to make this part of the story clear, the present status and the early historical background of tobacco culture in the United States will be briefly sketched.

TOBACCO A WORLD-WIDE CROP

Growing tobacco is an intensive form of farming, and in the centers of heaviest production it is often the principal cash crop. The average area in tobacco per farm is only about 6 acres. The crop has a relatively high value per acre, but the cost of production also is high, chiefly because of the large amount of labor required. On the average farm only certain areas are capable of producing tobacco of the highest quality, but in most centers of production the acreage of soil well suited to tobacco is usually large enough so that crop rotation can be practiced. This is a matter of importance in the control of diseases and insect pests and in obtaining high-quality leaf. In some sections, however, tobacco has been grown successfully on the same land year after year over a long period, without rotation.

Few staple crops ordinarily show such a wide range in gross returns per acre, depending on the quality or grade of the product. Although the hazards of commercial tobacco culture are numerous and often serious, under favorable conditions the crop is an attractive one for the average farmer in the recognized producing areas because of the possibility that he may get high returns when he has a high-quality product.

For the past 10 years the tobacco crop in the United States has averaged about 1,350,000,000 pounds, grown on 1,740,000 acres and having an estimated farm value of $214,000,000. This country is the leading world exporter and exports of leaf tobacco have averaged 500,000,000 pounds a year. Imports of foreign types have amounted to 70,000,000 pounds a year, mostly cigar wrapper from Sumatra and Java, cigar filler and wrapper from Cuba, cigar filler from the Philippines, and cigarette leaf from Greece and Turkey. Important quantities of Puerto Rican filler leaf are used in the manufacture of cigars.

The principal tobacco-producing States and the approximate average percentage of the total crop produced by each for the past 5 years are: North Carolina, 36; Kentucky, 26; Tennessee, 8.7; Vir-

ginia, 6.7; South Carolina, 5.3; Georgia, 3.6; Pennsylvania, 2.7; Ohio, 2.5; Wisconsin, 2; Maryland, 1.9; Connecticut, 1.6; Indiana, 0.8; Massachusetts, 0.5; Missouri, 0.5; Florida, 0.5; West Virginia, 0.25. North Carolina and Kentucky produce more than 60 percent of the crop, and these States, together with Tennessee, Virginia, South Carolina, and Georgia, account for than more 85 percent.

The crop is grown all over the world. Exclusive of China, world production is estimated at approximately 4.5 billion pounds, and the output of China probably would raise the total to more than 5 billion pounds. India is outstanding in point of total output, apparently producing about the same amount as the United States. The combined production of the two countries accounts for somewhat more than half of the world crop. Although accurate data are lacking,

SINCE *our standard types of tobacco are highly susceptible to most of the diseases, there is a pressing need for introducing resistance, without sacrificing quality, for practically every type and every producing area. General estimates of the losses from tobacco diseases are not available, but two specific examples may be cited. In North Carolina alone, root knot and wilt cost the growers at least $5,000,000 annually. In Pennsylvania wildfire reduces the value of the crop in some years as much as 50 percent. The magnitude of the breeder's task needs no emphasis. Up to now, investigators have attempted to develop varieties resistant to individual diseases, but the logic of combining in one variety resistance to more than one disease cannot be escaped and must be met.*

China doubtless ranks third in importance, accounting for 10 percent or more of the total world production. The remaining countries producing 100,000,000 pounds or more, in the order of their rank, are the Union of Soviet Socialist Republics, Brazil, Japan, Italy, Greece, and the Philippine Islands. The Netherland East Indies ranks second to the United States as an exporting country, followed in order by Greece, Turkey, Bulgaria, the Philippine Islands, and Cuba.

EARLY HISTORY OF TOBACCO CULTURE

Tobacco is one of the products given to the world by the natives of the Americas. When the Spaniards landed in Mexico in 1519, they found the people of Yucatan cultivating the strange plant with much care and skill, and using it both for smoking and as snuff (fig. 8). The conquerors were themselves conquered by the gentle weed.

Using seed from Yucatan, they began culture of the crop in Santo Domingo about 1531, and it was soon extended to Trinidad. Commercial production began in Cuba considerably later, about 1580, and was highly successful from the outset. In Venezuela the Spaniards also established commercial culture at about the same time, at Varinas near Cumana, and the product soon became famous for its excellence. In Brazil, culture by the Europeans apparently began in Bahia about 1600.

There are apparently no worth while very early descriptions of the types of tobacco grown by the Indians and the European colonists of the West Indies, Mexico, and South America. However, there is a partial description, dated as early as 1667, of four distinct forms of *Nicotiana tabacum* in cultivation in the West Indies at that time.

FIGURE 8.—Two species of tobacco cultivated extensively by the aborigines when the first colonists came to North America: *Nicotiana rustica* (*A*) and *N. tabacum* (*B*), showing buds, flowers, and green seed pods (drawn by H. A. Allard).

These are given as (1) Green Petun or Big Petun, so-called because of the brilliant green color of its leaves; (2) Tongue, described as resembling in shape the tongue of the ox; (3) Amazon, so-called because it was brought from the region of the Amazon River; (4) Varinas, deriving its name from the settlement in Venezuela from which the seed was obtained.

Green Petun is described as the most beautiful, with leaves 2 feet long and a foot wide, fleshy, downy, sappy, of a fine green color but shrinking markedly when dried so that large yields were never obtained. The Tongue variety produced leaves even somewhat

longer but only 7 to 8 inches in width, fleshy, oily, strong, less sappy than those of the Green Petun. There was less shrinkage in drying and good yields were obtained. The Amazon produced leaves as long as those of the preceding varieties but broader and more rounded at the end. The principal veins of the leaf tended to form right angles with the midrib, while in the other varieties they followed the contour of the leaf and sloped toward the tip. The leaves were very thick and fleshy, and although apparently they were very sappy, there was relatively little shrinkage in drying and the yield was good. The freshly cured leaf possessed a strong, disagreeable odor and when used caused dizziness and nausea. However, after fermentation the quality was excellent. The Varinas produced small leaves rarely 6 inches in length, narrow, very pointed, sappy, and shrinking so markedly in drying that it was a poor yielder. The leaf was mild and highly aromatic so that in mixtures no more than a fourth of it would impart its aroma to the whole. For this reason the Varinas was often adulterated with the less expensive sorts. It will be seen that of the four varieties under cultivation, two were imported from South America and probably one or both of the remaining two were introduced from Mexico.

In the northeastern part of the continent, tobacco culture was begun at Jamestown by John Rolfe in 1612. By 1616 culture of the crop had become general in the colony, and in 1619, 20,000 pounds of leaf were shipped to England. Although precise information on the question is lacking, it seems clear that at the outset or shortly thereafter, *Nicotiana rustica*, the plant grown by the natives in this region, was supplanted by *N. tabacum*, seed of which probably was obtained from South America or the West Indies. Moreover, as early as 1632 it was provided by law that only the "long sortes" be grown, showing that different varieties of the species were under cultivation.

There were, in fact, not only two distinct sorts in general use, known as Aronoka (Orinoco) and Sweet Scented, but numerous subvarieties or strains of each of these were recognized and given the names of prominent growers associated with them. It was in this manner that the sort known as Pryor received its name at that time. The Orinoco was described as having a sharp pointed leaf and yielding a stronger product, while the Sweet Scented had a rounder leaf, with fine veins, and was mild. Whether the Orinoco and Sweet Scented were closely related to, or identical with, any of the four sorts employed in the West Indies is not clear. The Orinoco, which presumably was obtained directly or indirectly from the region of the Orinoco River, still survives, at least in name, but the Sweet Scented as such has long since disappeared. Tobacco culture was extended into southern Maryland about 1635, and probably the Virginia sorts were grown at the outset.

It is apparent that numerous sorts of *Nicotiana tabacum* were available to the aborigines and the early settlers. Unfortunately the early descriptions of the sorts most used commercially in the West Indies and in Virginia are too meager to permit of close comparison with the many forms now employed. Since divers sorts were grown in the same locality, occasional hybridization must have occurred, resulting in modification of the original types, and thus there can be no assurance that present-day varieties closely conform to any of the original forms. As will be developed more fully later, most of the standard varieties and their numerous strains now grown in the United States appar-

ently have been derived from two original stem varieties, namely, Virginia or Orinoco, and Maryland Broadleaf. In the botanical literature on *N. tabacum*, Maryland and Virginia are recognized as distinct varieties, and in some instances they have even been classed as distinct species. The terms macrophylla (large leaf), latissima (very broad), and latifolia (broad leaf) have been used as synonyms for Maryland, although the descriptions do not closely apply in all respects to the Maryland types now in cultivation.

The Rapid Spread of Cultivation

We are accustomed to thinking of communication in the sixteenth century as being extremely slow; but within 25 years after the Spaniards began growing tobacco in Santo Domingo, it was being grown in Europe, and by the time John Rolfe made his first plantings, tobacco culture had apparently spread throughout Europe and the Far East.

In Europe the plant was first grown as an ornamental and for medicinal purposes, but it soon came to be used as it is now. On the Continent it was consumed in the beginning chiefly in the form of snuff, but in England pipe smoking at once became popular.

Tobacco was first grown or became known in France in 1556, in Portugal in 1558, in Spain in 1559, and in England in 1565. Various names were at first applied to the plant, including *Nicotiana*, after Jean Nicot, French ambassador at Lisbon. Nicot was one of the first to grow tobacco in Portugal, and was largely responsible for making the plant known at the royal court in Paris; and it was the Duc de Guise who proposed the name *Nicotiana* in 1585. (Actually, tobacco was first grown in Portugal in 1558 by De Goes, a friend of Nicot's, in the Royal Gardens at Lisbon. De Goes gave seed to Nicot, who grew it in 1559.) However, the name tobacco had become established in North America and was able to survive all others for common usage. Early writers differ as to the origin of this name, but it seems to have been applied originally not to tobacco itself but to a type of tube used by the aborigines for inhaling the smoke from the tobacco, or to a cylinder of tobacco prepared for smoking.

The tobacco grown in France and Spain was *Nicotiana tabacum*, from seed originating in Brazil and Mexico. The species first grown in Portugal and England was *N. rustica*, the seed in Portugal coming from Florida, while that used in England came from Virginia.

By 1600, or thereabout, tobacco had been introduced into Italy, Germany, Norway, Sweden, Russia, Persia, India, Indochina, Japan, possibly China, and on the west coast of Africa. With few if any exceptions culture of the crop was quickly established in these countries, although it has not survived in all cases. While both *Nicotiana tabacum* and *N. rustica* were introduced into various foreign countries at the outset, little is known as to the forms of these species originally employed in culture and their relationship to the varieties now in use in these countries.

From the small beginning at Jamestown, the production of tobacco in Virginia and Maryland increased rapidly, for it was about the only commodity the colonists could produce to exchange for the many manufactured products they required from Europe. From the crop of 20,000 pounds in 1618 at Jamestown, exports in 1627, only 9 years later, had increased to 500,000 pounds. In fact, although the foreign market rapidly expanded, production increased at an even greater

rate. The total exports for Maryland and Virginia were 1,500,000 pounds in 1639, but the value per pound had declined from nearly 55 cents in 1619 to about 6 cents. At the outbreak of the Revolutionary War, exports of tobacco had increased to about 100,000,000 pounds, nearly all of which was produced in Virginia and Maryland. After the close of the Revolution, culture was extended into North Carolina, Kentucky, Tennessee, Ohio, and Missouri, and later into several other States. Domestic manufacture of tobacco first assumed importance after the Revolution and has continued progressively to absorb an increasing portion of the crop, until at present more than half of the total production is utilized for this purpose.

THE BACKGROUND OF TOBACCO TYPES

Development of the numerous standard varieties now in use is very closely linked with expansion of tobacco culture into new territory and its evolution over a long period into a highly specialized industry, based on the production of numerous standardized commercial types of leaf. Today, each of the types produced possesses distinctive characteristics and is designed to meet exacting and relatively fixed trade requirements for specific manufacturing purposes. For example, certain types are used almost exclusively in the manufacture of cigars while other widely different types are especially suited for cigarettes. These cigar and cigarette types are essentially noncompetitive since they are not interchangeable for manufacturing purposes.

As tobacco growing was pushed farther and farther into new territory, marked differences in soil type and in climate were encountered and it was soon learned that these influences greatly changed the properties of the tobacco. With increasing specialization in tobacco manufacturing, based at first mainly on production of snuff and pipe-smoking products and subsequently on manufacture of specialized forms of chewing products, cigars, and, finally, cigarettes, it was discovered that the product of some particular area or areas was especially suited to the manufacture, for example, of a particular sort of chewing tobacco, while other areas yielded a desirable cigar wrapper or perhaps a good cigar filler, and so on. As a consequence, production of each principal type of leaf became more or less definitely localized. It was established also that the properties of the leaf may be greatly modified by changes in methods of growing and curing the crop. Thus cultural practices in each producing area are modified so as to accentuate the natural influences of environment in developing the properties of the leaf desired for the particular type being grown there.

Within each principal commercial leaf type there is a wide range of grade or quality, and here again local differences in soil and weather, and in cultural practices, play an important part. For one type the leaf may be valued for its extreme length and narrowness, while in another type a small broad leaf is desired; for one type the leaf should have a clear lemon or orange color, in another it should be almost black; in one case it should be very thin and elastic, in another thin but not elastic, in still another very thick and elastic; in some instances pronounced aroma is wanted, in others only weak aroma; for some types a very strong leaf is desired, but in others a very mild product is preferred. As illustrative of the effects of cultural practices on type or grade, it may be mentioned that, independently of other factors,

low topping of the plants in the field would be ruinous in the production of cigar wrapper leaf, but high topping would be equally unsatisfactory in producing dark fire-cured tobacco.

The principal commercial types or groups of types of leaf tobacco, the areas in which they are chiefly grown, and the uses made of them are indicated in table 2.

Table 2.—*The principal commercial types of tobacco, areas in which they are grown, their chief uses, and the varieties used in their production*

Type of leaf	Area in which mainly grown	Chief use	Variety of seed
Fired-cured (U. S. types 21–24).	Central Virginia, western Kentucky, and northwestern Tennessee.	For export, manufacture of snuff and plug wrappers.	Orinoco.
Dark air-cured (U. S. types 35, 36, 37).	Immediately east of fire-cured area of Kentucky and Tennessee, and in north-central Virginia.	For chewing plug and export.	Orinoco, One Sucker.
Maryland (U. S. type 32)	Southern Maryland	For cigarettes and export.	Maryland Broadleaf.
Cigar wrapper, shade-grown (U. S. types 61, 62).	Connecticut Valley and Quincy, Fla.	Cigar wrapper	Cuban, Florida 301, Round Tip.
Cigar binder (U. S. types 51, 52, 54, 55).	Connecticut Valley, southern and southwestern Wisconsin.	Cigar binder	Connecticut Broadleaf, Havana Seed.
Cigar filler (U. S. types 41–44).	Lancaster, Pa., and southwestern Ohio.	Cigar filler	Pennsylvania Seedleaf, Ohio Seedleaf, Zimmer Spanish, Little Dutch.
Flue-cured (U. S. types 11–14).	Southern Virginia, northern and eastern North Carolina, eastern South Carolina, southern Georgia, northern Florida.	Cigarettes, pipe and chewing tobaccos, and for export.	Orinoco.
Burley (U. S. type 31)	Central and northern Kentucky, southeastern Indiana, southern Ohio, western West Virginia, eastern and central Tennessee, western North Carolina, western Virginia.	Cigarettes, pipe and chewing tobaccos.	White Burley.

THE PRESENT VARIETIES

The immediate origin and the development of the standard varieties now used in culture of the burley and most of the cigar types of tobacco are fairly well known, but only meager information is available on the history of varieties employed in growing the much older dark air-cured, dark fire-cured, and the Maryland or the comparatively young flue-cured types. Undoubtedly the original varieties have undergone considerable modification as a result of accidental crossing and selection on the part of growers over a long period since the beginning of culture in Virginia and Maryland and subsequently in other States. Distribution of present tobacco varieties, including new productions by breeders, coincides essentially with distribution of the standard commercial leaf types, for with very few exceptions these varieties are not interchangeable in the different types.

Dark Fire-Cured and Dark Air-Cured Varieties

In the dark fire-cured and air-cured types, the cured leaf is dark in color, thick, quite heavy, oily, tough, and high in nicotine content. The fire-cured product possesses a characteristic creosotelike odor derived from the fuel used in curing. Fire-cured types of tobacco have always been chiefly used for export, and at present about two-

thirds of the output is exported. The remainder is mainly employed in production of snuff and chewing plug. On the other hand, about 75 percent of the dark air-cured types is used in domestic manufacture, especially for plug chewing tobacco.

Of the present-day commercial types, the dark fire-cured and dark air-cured of central Virginia, western Kentucky, and northwestern Tennessee most nearly represent the original type grown at Jamestown. Fire-cured tobacco in the process of curing is subjected to the smoke from slow wood fires on the floor of the curing barn, while air-cured leaf is allowed to cure or dry in ventilated barns without the use of artificial heat except perhaps under special conditions. The rich river-bottom lands of the tidewater section where this type was originally produced were of a light, sandy nature, but as culture was extended into the Piedmont and eventually into Kentucky and Tennessee, it was found that the much heavier loam and clay soils produced a better grade of leaf. Consequently tobacco culture eventually was abandoned in the tidewater section.

FIGURE 9.—Plant of the Orinoco variety, topped in accordance with usual cultural practice for the flue-cured type of leaf. The Orinoco in its numerous forms is the most widely cultivated of all domestic varieties, being used generally for production of flue-cured and most dark air-cured and fire-cured types of leaf.

In Virginia various strains of the Orinoco (fig. 9) differing somewhat in size and shape of leaf and other characteristics are chiefly used in growing the dark fire-cured and dark air-cured (so-called sun-cured) types. The present Orinoco apparently represents a survival, doubtless in modified form, of the Orinoco variety originally grown at Jamestown. Among the strains now chiefly grown are Lizard Tail, Big Orinoco, Narrow Leaf Orinoco, and Kentucky Little Yellow. A typical plant of the Orinoco is shown in figure 9. In Kentucky and Tennessee the principal dark varieties belong mostly to the Pryor group. According to early authorities, the Pryor, as originally grown in the tidewater section of Virginia, was merely a form of Orinoco. Since tobacco culture was carried into Kentucky and Tennessee from Virginia, it seems probable that the present Pryor is a survival of the original Pryor of the latter State, and therefore is closely related to, if not essentially identical with, Orinoco. The latter also is grown to some extent in the dark-tobacco districts of Kentucky and Tennessee. Among the principal strains of Pryor may be mentioned Blue Pryor, Yellow Pryor, Madole, and Yellow Mammoth.

A fairly distinctive variety used in the culture of dark air-cured leaf in Kentucky and Tennessee is known as One Sucker, and the type of leaf produced also is known by the same name. The One Sucker produces a very long, narrow, heavy leaf, having a large midrib with which the principal veins form a very acute angle. This variety derives its name from the fact that it is supposed to sucker somewhat less freely than most other varieties. The origin of the One Sucker is uncertain, but the leaf characteristics suggest that it may be a survival of the Tongue, one of the four varieties described in the West Indies in 1667.

Up to the present, comparatively little has been done in the improvement of the dark fire-cured and air-cured varieties by breeding. In the Virginia sun-cured district a selection from Narrow Leaf Orinoco, made by the State Agricultural Experiment Station, which is believed to be resistant to the blackfire disease, has come into extensive use by growers. In the sun-cured and in the fire-cured districts of the State the Lizard Tail and similar strains of Orinoco have been reported as being among the best available sorts.

Figure 10.—Maryland Broadleaf in the early stage of flowering. This is the parent variety from which the northern Broadleaf or Seedleaf cigar tobacco varieties were derived. White Burley also probably originated as a mutation in this variety.

Maryland Varieties

The Maryland is the second oldest type grown in the United States. As now produced in southern Maryland, this type has distinctive properties which sharply distinguish it from other types with the exception of Burley. The latter and the Maryland type show considerable similarity in properties. When cured, the Maryland leaf is of an extraordinarily light, dry, chaffy character, low in nicotine, light reddish brown in color, and relatively thin, and it has a rather weak aroma and possesses excellent burning qualities. The leaf should be relatively large and broad. Formerly Maryland tobacco was chiefly an export type, but at present the better grades are used mainly in the manufacture of blended cigarettes.

There is some doubt as to the original source of the Maryland Broadleaf of today (fig. 10). It appears to resemble the Sweet Scented of early colonial days in Virginia, as far as may be judged from fragmentary early descriptions of the latter, although as now grown it is not outstandingly "sweet scented." Since tobacco was

grown immediately south of the Potomac in those days, it is likely that both the Orinoco and the Sweet Scented were introduced into southern Maryland and that the latter was found to give better results in the new area. One early writer states that the Maryland variety came from Mexico, but even so it may have come by way of Virginia. Until quite recently narrow leaf forms also were grown in southern Maryland, but these did not resemble the Orinoco of Virginia. At present, strains designated as Medium Broadleaf, which produce a somewhat narrower leaf than the ordinary broadleaf strains, are popular among growers.

A peculiar form of the Maryland discovered some years ago is of interest because of its exceptional vegetative vigor and the very large number of leaves it produces under Maryland conditions. This variety, which appeared as a mutation, is known as Maryland Mammoth. Normally it does not flower during the growing season. Since flowering and fruiting represent the final stages in the maturing of the tobacco plant, and the development of terminal flowers prevents further upward growth, Maryland Mammoth may be thought of as continuing growth indefinitely because it never reaches maturity from the biological standpoint. It was largely through a systematic study of this peculiar behavior that the phenomenon of photoperiodism or the effect of length of day on the growth and maturing of plants was discovered. Under suitable conditions this variety is capable of producing large yields of high-quality leaf, and from a cross with the Standup form of White Burley a "mammoth" or non-flowering form of considerable promise for Maryland conditions has been obtained recently. This form shows the stand-up or erect habit of growth and produces large yields of high-quality leaf. From a cross of ordinary Maryland with a black root rot-resistant strain of Burley developed at the Wisconsin Agricultural Experiment Station, resistant forms apparently suitable for Maryland conditions also have been obtained.

Cigar-Leaf Varieties

It was about a hundred years ago that cigar leaf began to be recognized as a distinct commercial type. Actually, cigar tobacco as now grown is divided into three principal types or type groups—cigar wrapper, cigar binder, and cigar filler. Wrapper leaf is grown mainly under artificial shade in the Connecticut Valley and in the vicinity of Quincy, Fla. Binder leaf, which in cigar manufacture is used to hold the shape of the filler or core of the cigar, is produced chiefly in the Connecticut Valley without the use of shade, and in southern and southwestern Wisconsin. Lancaster County, Pa., and the Miami Valley section of southwestern Ohio are the principal centers of filler-leaf production. Formerly cigar leaf also was produced in important quantities in several other areas.

The cigar was a favorite form of smoking among the European settlers in the West Indies almost from the outset, and during the latter portion of the eighteenth century cigars were imported into this country in important quantities, mainly from Cuba. Domestic manufacture of cigars also became of some importance at this time in Philadelphia and soon afterward in Connecticut, both domestic and imported "Spanish" leaf, mostly from Cuba and Brazil, being used. At that time tobacco culture in the present cigar-leaf-producing areas

was of little importance. About 1825 it began to be recognized that the Connecticut Valley was well adapted to the production of cigar leaf. At first a narrow-leaf variety known as Shoestring was grown, but about 1833 the Maryland Broadleaf was introduced and under the local soil and climatic conditions was found to produce a very large, broad, thin leaf with fine veins, very elastic, having an agreeable taste, a pleasant but not pronounced aroma, and good burning qualities. This introduction had an important influence in furthering development of the local industry, and Connecticut Broadleaf or Seedleaf, of which there are numerous strains, is still a leading variety in local production of binder leaf.

FIGURE 11.—A form of the Cuban variety. This variety is employed in the culture of cigar wrapper under artificial shade in the Connecticut Valley and in the production of cigar filler and wrapper in Cuba.

Culture of cigar leaf did not become important in Pennsylvania and Ohio till the middle of the last century, an Wisconsin became and important producing State about 20 years later. While other varieties of unknown origin also were used at the outset, Broadleaf or Seedleaf introduced from the Connecticut Valley soon came to be standard for these areas, although more recently the Seedleaf has been largely abandoned in Wisconsin. The various strains of Seedleaf now in use in Pennsylvania and Ohio, however, have come to differ somewhat from the Connecticut Seedleaf, and all differ more or less from the parent Maryland Broadleaf. Another distinctive variety introduced into the Miami Valley at an early date and still of some importance locally is known as Little Dutch. Nothing is known as to the origin of this variety, except that it is said to have been introduced into Ohio from Germany. It possesses very narrow leaves of erect habit of growth, has a peculiar odor in the field, is early in maturing and highly resistant to black root rot, and has a characteristic aroma when smoked.

About 1870 an important new introduction was made in all of the four principal cigar-tobacco growing areas. In the Connecticut Valley this introduction came to be known as Havana Seed or Connecticut Havana to distinguish it from the directly imported Cuban. In the Ohio cigar-tobacco district the variety received the name of Zimmer Spanish, the last term of the name indicating its West Indian

origin and the first being that of a pioneer grower of the variety. Similarly in Wisconsin it was given the name Comstock Spanish.

It appears that this variety was developed in the Connecticut Valley as a selection from imported Cuban, which frequently has been found to be composed of many distinct strains. Finding it necessary to practice seed selection in order to obtain the new variety in pure form, growers received the impression that the freshly imported variety underwent an important progressive transformation during the first few years of culture in the new environment, a notion that still is rather widely prevalent. Actually, however, the diversity of forms had a genetic basis and was not due to environment. Havana Seed at once became a very important variety and has remained so. It is a competitor of Seedleaf in the production of cigar binder in the Connecticut Valley and of cigar filler in Ohio, and it has practically supplanted Seedleaf in the production of binder in Wisconsin. Havana Seed has a larger, longer leaf and more upright growth habits than ordinary Cuban. It produces a smaller, somewhat narrower, and a distinctly more erect-growing leaf than the Seedleaf and yields considerably less per plant.

The most recent addition to our commercial types of leaf tobacco is the shade-grown cigar-wrapper leaf which first became firmly established about 1906 in the Connecticut Valley and in the Quincy, Fla., district, as a result of extensive experiments conducted by the United States Department of Agriculture and the State experiment stations. Previously the Broadleaf and Havana Seed, grown without shade, had been largely utilized for wrapper. In the early years of the shade industry the Sumatra variety was tried but proved unsatisfactory, and in the Connecticut Valley it was replaced by selected strains of imported Cuban (fig. 11). The selection and introduction of suitable strains of Cuban through the joint efforts of the Bureau of Plant Industry and the Connecticut Agricultural Experiment Station appears to have had an important effect in placing the shade industry on a sound basis. Numerous strains differing somewhat in leaf characteristics are commonly found in the Cuban, but as now grown under shade in the Connecticut Valley the variety is fairly well standardized. The Cuban has smaller, less pointed leaves and longer internodes, and it is taller than Broadleaf or Havana Seed. In the Quincy district the Sumatra was replaced by a variety known as Big Cuban which is said to have originated from a cross between Sumatra and the ordinary Cuban, although the details of its development are not known.

Up to the present the cigar-tobacco varieties have received more attention from breeders than the other commercial types of leaf. Beginning about 1900, experiments in the production of improved varieties through hybridization and selection were undertaken in several of the cigar-tobacco areas. However, the difficulties involved in securing the desired recombinations of visible leaf characteristics by these methods without upsetting the various elements of quality in the cured product were not fully understood. While in several instances new forms were obtained which showed much promise in the field, notably the Halladay Havana, from a cross of Havana Seed on Sumatra, nearly all proved to be unsatisfactory to the manufacturer for one reason or another and had to be abandoned. Some years later, however, a new variety known as Round Tip was produced at the Connecticut Agricultural Experiment Station (East

and Jones, 1921), in accordance with a clearly defined objective and plan of procedure, which achieved considerable success and has served to indicate that there are possibilities in the creation of improved varieties when all necessary precautions are observed. Nevertheless, the subsequent history of this variety in culture further emphasizes the difficulties and uncertainties of the problem of developing new varieties that will be acceptable to the trade with respect to all elements of quality.

Round Tip was produced from a cross of Connecticut Broadleaf on Sumatra. It combines, at least in some degree, the large size of leaf, the short internodes, and the high yield of the Broadleaf with the round tip, erect growth habit, large number of leaves per plant, and light color of leaf of the Sumatra, and it is resistant to black root rot. The cured leaf appeared to be quite satisfactory with respect to flavor, elasticity, and combustibility. In Connecticut this variety gave very promising results when grown as a substitute for Havana Seed in the production of so-called "primed Havana" wrapper leaf. Subsequently, however, culture of the primed Havana type was abandoned and there appeared to be no further place for Round Tip. Curiously enough, when tried under shade in the Florida area, Round Tip proved to be superior to the Big Cuban and for a time it practically replaced the latter. Unfortunately, the black shank (*Phytophthora*) disease soon became epidemic and Round Tip proved to be highly susceptible, so that again its culture was greatly reduced.

The most recent productions in the cigar-wrapper varieties are black shank-resistant substitutes for Round Tip in the Quincy area. The Florida Agricultural Experiment Station first developed highly resistant strains of Big Cuban and ordinary or Little Cuban through systematic selection. The former, like the parent variety, is rather deficient in quality, while the latter gives low yields. From a cross of these resistant strains a variety designated as 301 was obtained through selection for six generations. This combines high resistance to black shank with reasonably good quality of leaf, and it is now widely grown.

As regards the cigar-binder types, the Wisconsin Agricultural Experiment Station in 1915 released an improved strain of Havana seed which came to be widely grown in the State because of its erect growth habit, uniformity, broad leaves from top to bottom, increased number of leaves per plant, and the high quality of the cured leaf. This strain was obtained by selection in a cross of two fairly distinct strains which had been isolated from Havana Seed introduced from Connecticut. However, the new strain, known as Havana No. 38, is susceptible to root rot and for this reason has not been so extensively grown in recent years.

To overcome this difficulty, Havana No. 38 was crossed with a selection from a strain of Havana Seed locally known as Page Comstock which was resistant but did not possess desirable habits of growth. From this cross was developed Havana No. 142, which proved to have greater resistance to root rot than the more resistant parent. It also has desirable growth habits and is a good yielder, although it is somewhat later in maturing than ordinary Havana Seed. While there has been some difference of opinion among manufacturers as to the quality of leaf produced by this strain, it has been widely grown in the State and there is no question as to its

superiority over susceptible strains of Havana Seed when planted on root rot-infested soil. From the same cross another resistant strain known as Havana No. 211 was later developed. This strain appears to have certain advantages over Havana No. 142 with respect to quality and has given promising results both in Wisconsin and in the Connecticut Valley.

In the Pennsylvania cigar-filler area two new sorts of Pennsylvania Seedleaf have been introduced in recent years by the State agricultural experiment station and the Bureau of Plant Industry cooperating, and these sorts have been extensively grown. The Schwarr-Hibshman was developed by selection in a cross of the local Schwarr and Hibshman strains, and the Olson Broadleaf was obtained from a cross of local Seedleaf and Pennsylvania Havana seed. These new sorts give good yields, are early maturing and relatively resistant to root rot, and produce leaf of standard quality.

Flue-Cured Varieties

Flue-cured tobacco, often spoken of as bright tobacco, owes its name primarily to the unique method employed in curing the leaf. Artificial heat is supplied through a system of flues or pipes so that the leaf does not come in contact with smoke from the fuel used, and the curing process is rapid. This has come to be by far the world's most important commercial type of leaf tobacco in point of quantity produced. It is grown mainly in southern Virginia, northern and eastern North Carolina, eastern South Carolina, southern Georgia and northern Florida. Among the outstanding characteristics of the cured leaf are its bright lemon to orange color, its distinctive aroma, and its high content of sugar. Its principal uses are for domestic manufacture of straight and blended cigarettes, pipe-smoking and plug-chewing tobaccos, and for export.

The type as now grown is essentially the result of change in soil type from the heavy silt loams of central Virginia to the less fertile light gray soils of the North Carolina border counties and later the Coastal Plain section as culture was extended into these areas, together with subsequent changes in the method of curing and in cultural practices. There was no significant change in the varieties of seed used. The lighter soils of the central border counties produced a leaf of much lighter color, sweeter, and finer in texture, which quickly found favor in the export market and for the manufacture of chewing tobacco. For leaf of these characteristics it was found advantageous to use less heat in curing, and about 1825 charcoal as fuel came into use in order to eliminate the effect of smoke on the odor and taste of the leaf. Metal flues for supplying heat in the barn without admitting smoke came into general use after the Civil War. Toward the close of the last century culture of flue-cured tobacco was introduced into eastern North Carolina and South Carolina and there increased very rapidly. Finally, about 15 years ago, culture of this type was further extended into southern Georgia and northern Florida.

As already indicated, the Virginia Orinoco in its various forms was used from the outset in the culture of the type now known as flue cured. Apparently the present strains of the Orinoco as a whole do not differ greatly from those employed originally. Broadly speaking, the larger broad-leaf forms are preferred for the lighter soils of the Coastal Plain and the eastern portion of the Piedmont areas,

while the narrow-leaf forms are popular in the western portion of the Piedmont producing area. This is in accord with the fact that, other things being equal, a heavy close-textured soil tends to produce a smaller, narrower but thicker leaf than a light, open soil. Among the more popular older strains are Yellow Orinoco, White Stem Orinoco, Little Orinoco, Gooch, Adcock, Yellow Pryor, and Silky Pryor. At present an extremely large number of so-called varieties are used in growing flue-cured leaf, but these are merely strains, most of them so similar as to be almost indistinguishable from one another. Of those most widely used at present, mention may be made of Cash, Jamaica, Virginia Bright, Bonanza, Yellow Mammoth, and the old White Stem.

Comparatively little has been done in the improvement of flue-cured varieties by breeding. In the period 1929–32 the Coker's Pedigreed Seed Co. in South Carolina released two improved strains of Jamaica and one each of Yellow Mammoth, Bonanza, Virginia Bright, and Cash. All of these strains were obtained by straight selection for yield, quality, and disease resistance. They have been grown extensively, more particularly the selection of Jamaica known as Gold Dollar, and appear to have given generally satisfactory results. At the Oxford, N. C., tobacco station three strains resistant to black root rot have been developed by selection from Jamaica, Paris Wrapper, and an unnamed form supposed to have originated from a cross of Warne on Big Gem. Of the three strains, the last-named shows the highest disease resistance, and it is a good yielder and appears to produce leaf of excellent quality. As yet this strain has been grown only to a limited extent but has given very promising results. It is designated as Special No. 400. Pure lines of White Stem, Virginia Bright, Cash, Jamaica, and Bonanza selected for growth habits, yield, and quality were released to growers in the period 1920–27, the two first being especially adapted to the light, sandy soils and the others to heavier soil types.

Burley Varieties

The commercial type of leaf known as Burley represents the only instance in the history of the tobacco industry in which the discovery of a distinctly new variety, by one of those lucky accidents that shape the course of history, has been solely responsible for the establishment of a new, highly important commercial leaf type. Moreover, the leaf type bears the same name as the variety. Burley, which is second to the flue-cured type in importance, is grown chiefly in central Kentucky; certain areas of West Virginia, Ohio, and Indiana bordering on the Ohio River; eastern Tennessee and portions of central Tennessee; and the extreme western part of Virginia and North Carolina. At present its principal uses are for the manufacture of blended cigarette and pipe and chewing tobaccos.

Tobacco was grown commercially in Kentucky and southern Ohio by settlers from Virginia and Maryland for many years before the appearance of the new variety. These settlers of course carried tobacco seed with them from their home States. In northern Kentucky and southern Ohio a very light, chaffy, reddish or cinnamon-colored leaf, almost free of gum, was produced from a variety or strain known as Burley. These characteristics of the leaf, which closely resemble those of the southern-Maryland product, made it

especially suitable for the manufacture of a form of chewing tobacco known as fine cut. The name Burley probably was derived from that of a grower just as in the case of the Pryor in Virginia, previously mentioned. There is little reason to doubt that the original Burley was a form of Maryland Broadleaf.

In 1864 George Webb, a farmer in Brown County, Ohio, observed in his tobacco seedbed, which is said to have been planted with Burley seed from Bracken County, Ky., a number of seedlings having a peculiar chlorotic appearance—that is, they were somewhat deficient in green coloring matter. These seedlings were discarded as being diseased, but when they appeared again the following year in a second planting of the original seed, some of them were grown to maturity. The mature plants, though otherwise normal, showed an almost pure cream color instead of the normal light green. The leaf cured to a light yellowish red color, and the light, chaffy, porous characteristics of the parent Burley were accentuated. Because of the peculiar creamy color of the stalk and the midrib and veins of the leaf, and the very pale greenish yellow color of the leaf web when mature, the new variety was called White Burley to distinguish it from the old Burley, which came to be known as Red Burley. The latter has long since lost its identity and the White Burley is now commonly spoken of simply as Burley.

The White Burley has never been a leading export type, but it played a very important role in shaping the course of domestic tobacco manufacture. Originally it was found to be excellent for the manufacture of fine cut, and consequently its culture increased very rapidly. Beginning about 1875 it came to be recognized that the heavier grades of Burley were especially adapted to the manufacture of strongly sweetened plug because of the remarkable capacity of the leaf to absorb flavoring sauces. This discovery resulted in enormous development in manufacture of the new type of plug and a greatly increased demand for Burley leaf. As in the case of Orinoco and other distinctive varieties, numerous strains of Burley differing in erectness, leaf size, and other characteristics were developed, but during this period broadleaf, drooping forms of Burley, similar in general appearance and growth habits to the Maryland Broadleaf except in color, were in greatest demand for producing a tough filler leaf for plug. White Twist Bud, Lockwood, and Big Silk were popular strains.

Subsequently it developed that Burley leaf, especially that from the lowermost part of the plant which was classed as "trash" and previously had no ready outlet, is well suited for the production of blended pipe-smoking mixtures. Here again it found extensive use, particularly for production of the cut-plug type of pipe tobacco. Finally, as the use of chewing tobacco declined and the consumption of machine-made cigarettes began to increase with phenomenal rapidity, Burley once more demonstrated its general adaptability, for it has come to be a leading type in the manufacture of blended cigarettes. Thus, while the principal use of Burley has repeatedly shifted, in each case because of specific characteristics or properties, consumption has tended to increase over a long period.

However, the shift in principal demand from chewing to smoking grades of leaf called for modification in growth characteristics of the variety, in order to secure an increased proportion of smoking grades and a corresponding reduction in chewing grades in the crop. To meet this situation, recourse was had to culture of the so-called

stand-up strains with leaves of a more erect habit of growth, somewhat smaller in size but with a greater number per plant, and yielding a higher percentage of light-colored, light-bodied leaf than the broadleaf, drooping forms of Burley. Among the popular strains have been Judy Pride, Halley Special, Pepper, and Kelley.

Green coloring matter plays a vital part in the functioning of the leaves of plants, and perhaps because of its chlorotic characteristic, White Burley is a less rugged and vigorous plant than the typical green sorts. Consequently it does not yield as well when grown on soils of low fertility. Under such adverse conditions the leaf loses some of its desirable properties. Burley also is more severely affected by such diseases as mosaic than are most other varieties. On rich loam soils, however, it grows vigorously and is capable of producing good yields of light yellowish red leaf which is light-bodied, chaffy, and fine-textured, and has excellent burning qualities but weak aroma. These properties of the cured leaf make it especially valuable for blending with other types of leaf.

Burley is highly susceptible to the black root rot disease, and in recent years considerable attention has been given to the development of resistant strains. In 1919 the Bureau of Plant Industry (U. S. D. A. Bull. 765) reported results of experiments demonstrating the superiority of a highly resistant strain, obtained by selection, over the ordinary strains when grown on infested soil. However, the resistant strain was the drooping form of Burley, whereas the stand-up sorts are in much greater demand for production of cigarette leaf. More recently, several resistant strains of the stand-up form have been produced. In the period 1922–24 the Kentucky Agricultural Experiment Station released two strains obtained by selection from ordinary forms and designated as Strain W and Strain 36–12 which were moderately resistant to root rot. These strains have been largely superseded by White Burley No. 5, which was developed from a cross of the W strain on a cigar-tobacco variety and released in 1929. No. 5 is highly resistant, produces a leaf of good quality, and has been widely grown.

Foreign Types and Varieties

Of the great array of types of leaf grown in foreign countries, only a limited number enter into commerce in important quantities. There are three principal foreign types imported into the United States for use in domestic manufacture—Sumatra and Java cigar wrapper, Cuban cigar filler and wrapper, and so-called Turkish leaf, a cigarette type which is mainly imported directly or indirectly from Turkey and Greece.

The Sumatra variety is fairly distinctive, but numerous strains varying somewhat in various characteristics are in use. In the past this variety has been extensively tried in this country but without pronounced success, and it also has been employed in certain cases for hybridization with domestic varieties. Sumatra is relatively tall, with moderately long internodes, and it produces a fairly large number of medium-sized, round-tipped, broad, erect-growing leaves, of somewhat lighter green color than most varieties. It is resistant to black root rot.

The Cuban variety has been shown to consist of numerous races which ordinarily breed true to type. These races in some instances differ rather widely in number, size, and shape of leaf and other growth characteristics. Selected strains of Cuban are extensively

used in the culture of cigar wrapper under shade in the Connecticut Valley (fig. 11). It somewhat resembles Sumatra in general growth characteristics. As grown in Cuba this variety is famed for its excellent aroma, but experience has shown that expression of this characteristic is largely dependent upon the soil and climatic conditions under which the tobacco is grown. In other words, the same tobacco grown elsewhere does not give the same results.

The so-called Turkish or oriental tobacco of commerce is in reality composed of several types grown in different regions, chiefly in ancient Macedonia and in the general region of Smyrna and along the southern shore of the Black Sea in Asia Minor. The varieties used in producing these types differ decidedly in many respects, and even in the same district there are material differences in the varieties and strains grown. The more important Turkish varieties, though differing among themselves, are characterized as a class by relatively very small leaves which when cured possess a distinctive aroma, are mild, and have good burning qualities. The commercial types of chief importance in this country are those from Macedonia, Smyrna, and Samsun. Representative varieties from these regions have been grown for observation in the Bureau of Plant Industry. The Samsun variety is characterized by an ovate (egg-shaped) or almost cordate (heart-shaped) form of leaf, very broad at the base and having a naked petiole or leafstalk, very short internodes, and a large number of leaves per plant. Smyrna produces a relatively large leaf resembling Havana Seed in shape. A Dubek or Xanthi sort from Macedonia has an exceptionally broad and well-rounded leaf, distinctly smaller in size than the other two. It was found that when the plants were grown on fertile soil and widely spaced, the Turkish sorts produced surprisingly large leaves

The numerous sorts of both *Nicotiana tabacum* and *N. rustica* grown in India have been extensively studied by the Howards (*8*) and others in that country, and considerable work has been done in their improvement by breeding. These tobaccos, however, are of no special interest in this country. The same is true of the tobaccos grown in Italy, the Union of Soviet Socialist Republics, Germany, Rumania, and other countries in which some research in tobacco breeding has been conducted.

The Botany of the Tobacco Plant and the Studies Made in Genetics

IN ADDITION to the practical breeding work with tobacco, which develops out of economic needs, there has been a good deal of basic genetic research for which the tobacco plant furnished a convenient subject. This work is important as indicating the genetic basis for breeding programs. Before it is surveyed briefly, it will be well to include enough about the botany of the tobacco plant to make clear its general characteristics and its place in the plant world.

BOTANY OF THE TOBACCO PLANT

Tobacco belongs to the genus *Nicotiana* which was established by Linnaeus in 1753. *Nicotiana* is but one of a very large and important

family of plants known as the Solanaceae or nightshade family, which includes many of our most useful food and medicinal plants, some of the latter being highly poisonous. Among the members of the family are potato, eggplant, tomato, henbane, belladonna, garden peppers, ornamental petunias, salpiglossis, and many others. The greatest development of the entire family, as indicated by the number of genera and species, has been in the New World, more especially in Central America and South America.

In his original classification Linnaeus included the two species of tobacco chiefly cultivated by the North American aborigines and subsequently by the early colonists—*Nicotiana tabacum* and *N. rustica*. He was acquainted, however, with very few distinct species, probably less than half a dozen, including the two commercially useful species mentioned. Since the time of Linnaeus, many others have been discovered and the genus has grown to include a large assemblage of species, varieties, and forms. The genus has been revised but three times up to the present, the oldest systematic revision being that of Lehman in 1818. In 1852 Dunal made the second revision of the genus, and in 1899 O. Comes made the third and the latest systematic revision. There were about 50 species and as many varieties recognized at the time of Comes.

At the present time the genus *Nicotiana* is greatly in need of careful revision from the standpoint of systematic classification, but this becomes a problem of great difficulty because much of the original herbarium material is inaccessible and widely scattered in the herbaria of England, Europe, and South America. Although possibly 100 distinct species may comprise the genus *Nicotiana*, seeds of scarcely more than a third have been obtainable in this country.

Nicotiana is primarily a New World genus; in fact the only known exception is the species *N. suaveolens* and related forms occurring in Australia, and perhaps in other islands of the Australasian archipelago. The only species of economic importance are *N. tabacum* and *N. rustica*.

The species *Nicotiana tabacum* has slender tubular flowers with the flower tube greatly exceeding the calyx in length, and usually pink in color in our commercial types, although white and carmine-red forms of the species exist. The lobes at the upper end of the corolla are commonly distinctly separated, and acute or pointed. The leaves, which are usually sessile, that is, without a stalk, and auricled [5] or partly clasping the stem, vary greatly in size, the variation depending on the variety and conditions of growth. In some of the Turkish forms as grown commercially the leaves are very small, less than 6 inches long; in some of the larger growing varieties they may reach 2 to 3 feet in length. This species, like *N. rustica*, is covered with a sticky pubescence or hairy growth. The plant usually reaches 4 to 6 feet in height in the field.

The species *Nicotiana rustica* is characterized by pale yellowish flowers, with a short, thick corolla tube, having rounded lobes. The leaves are thick, broadly ovate (egg-shaped) with a distinct, naked petiole or leafstalk. The entire plant is beset with a very glutinous pubescence. It usually grows from 2 to 4 feet in height. The flowers of *N. tabacum* and *N. rustica* are shown in figure 8. Under favorable conditions, varieties of both of these species may possess a very high content of nicotine.

[5] Having an ear-shaped appendage at the base of the leaf. From Latin auris, ear.

Several species of tobacco are given a place among the garden ornamentals, including *Nicotiana sylvestris* and *N. alata*.

Native species of tobacco have not been found east of the Mississippi River. West of the Mississippi a number of small native species occur, covering portions of the territory from Texas to southern California and northward to British Columbia.[6] If the number of species is a criterion, the genus *Nicotiana* appears to have reached its greatest specialization in South America south of the Equator, and to have spread outward, ultimately to reach Central America, Mexico, and the western United States.

Since there are no eastern native species of *Nicotiana*, it would appear that the drier conditions of the Mexican highlands and the western area of the United States have been more favorable to the northern distribution and evolution of species than the more humid, originally heavily forested territory east of the Mississippi River and the Appalachian Mountains. Aboriginal man unquestionably has been a factor in the transplantation of at least two species far northward of their original habitat, especially in the eastern United States. This was a cultural introduction based on the usefulness of the plant for smoking, chewing, and snuffing.

FIGURE 12.—Prof. E. M. East, an outstanding geneticist whose extensive investigations in the genus *Nicotiana* have greatly advanced our knowledge of the genetics of tobacco. Professor East also has successfully applied genetic principles to the development of valuable new strains and varieties, notably the Connecticut Round Tip.

The species *Nicotiana rustica*, probably native to Mexico, which was widely cultivated by the aborigines, has tended to persist in Texas and also in the East wherever field conditions have given it some degree of freedom from competition with the native woody plants. The species *N. tabacum*, probably an introduction from South America, appears to be even more dependent upon open field conditions and is even less able to maintain itself without cultivation.

Nicotiana rustica was grown by the American aborigines throughotn the region to the east and immediately west of the Mississippi, from Canada to Mexico. *N. tabacum* was the principal aboriginal tobacco of the West Indies, most of Mexico, Central America, Colombia, Venezuela, the Guianas, and Brazil. Apparently *N. quadrivalvis* and its variety *multivalvis* were cultivated by the Indians of northwestern United States. According to Setchell (1921), *N. attenuata* was widely used by the Indians over the Southwest, most of the Plains area, and the North Pacific coast, and *N. trigonophylla* was employed by the Yumas of the Southwest for smoking.

[6] In the western area of the United States, the recognized native species are *Nicotiana trigonophylla* Dunal; *N. attenuata* Torr.; *N. repanda* Willd; *N. clevelandii* A. Gray; *N. bigelovii* S. Wats.; *N. palmeri* A. Gray; *N. quadrivalvis* Pursh, and its variety *multivalvis* Gray; *N. plumbaginifolia* Viv. *N. glauca* Graham, native to Argentina, has become widely established from Texas to southern California and Mexico.

Because of its many natural advantages, the genus *Nicotiana* was used extensively by hybridizers long before the days of Mendel, and it has continued to receive much attention in recent years by geneticists, notably East at Harvard (fig. 12) and Goodspeed at the University of California.

Inheritance in Species Hybrids

The F_1 generations of crosses between species furnish favorable material for the study of sterility, since they range from those that are entirely fertile to those that are completely sterile. In an analysis of published data on hybridization experiments, East (1928) found that in 228 combinations tried between 18 species, only 79 of these combinations produced hybrid plants. *N. tabacum* and *N. rustica* have been shown to contain 24 pairs of chromosomes, while the range in all known species in the wild is from 9 to 32. Successful crosses have been obtained between *tabacum* and the following species—grouped according to Goodspeed's classification—each having the number of pairs of chromosomes indicated: *Alata, sanderae,* and *langsdorfii* (9); *glauca* and *paniculata* (12); *sylvestris* (12); *tomentosa, tomentosiformis* (*rusbyi*) and *glutinosa* (12); *suaveolens* (16); *rustica* (24); *bigelovii* (24). In some cases viable seed are obtained with considerable difficulty, and in some instances, as in *rustica* × *tabacum*, the crosses can be made more readily in one direction than in the other. It appears that usually crosses between species differing in number of chromosomes are more likely to be successful when the species with the higher chromosome number is used as the female parent.

Inheritance of certain morphological or form characters has been studied in crosses between species of the *alata* group. Reciprocal hybrids of *Nicotiana langsdorfii* and *N. alata* were found to be identical and generally intermediate in characteristics, but the blue pollen and green flower color of the former were dominant over the ivory-colored pollen and white flower of the latter. In studies of flower size it was determined that in F_1 populations corolla length was as uniform as in the parents when self-fertilized, while the F_2 populations were three times as variable. The variabilities of F_3 families were always smaller than those of F_2 families. It appears that these color and size characteristics, as well as red and purple flower color in *N. sanderae*, are controlled in the main by a relatively small number of genes, although doubtless there are several less easily detectable genetic factors which modify their expression.

Of the *alata* group of species, *Nicotiana alata* and *N. sanderae* are usually self-sterile, while *N. langsdorfii* is self-fertile. According to East, self-sterility and cross-sterility in these species are dependent upon a limited number of genes functioning in such a way as to cause differential growth of the pollen tube.

In general, hybrids between species are intermediate with respect to growth habit and pattern of leaf and flower. These constitute the most obvious differences between the species, and apparently the differences can best be explained on the basis of a large number of nondominant Mendelian factors. East (1935) suggests that it is these genes that are of importance in evolution rather than the dominant qualitative factors that are usually studied by geneticists.[7]

[7] According to this conception, species have evolved through the building up of genes with different effects on the pattern of leaf, flower, growth habit, etc., each complement of such genes being capable of producing a distinct biotype with the ability to survive natural selection. The qualitative factors or genes, which usually are dominant, are mostly limitations on various physiological processes, involving, for example, such phenomena as dwarfism.

It has been suggested by Goodspeed that some, and possibly all, species containing 24 pairs of chromosomes have resulted from hybridization in which the numerical chromosome complement of both parent forms was retained, so that, added together, they gave 24 pairs of chromosomes in the progeny. Evidence has been presented that *Nicotiana tabacum* originated from a cross between a member of the *tomentosa* group and *N. sylvestris*, each having 12 pairs of chromosomes. In the same manner *N. rustica* may have resulted from hybrids between members of the *glauca* group with 12 pairs of chromosomes.

Genetic Studies in Nicotiana Tabacum

As has been pointed out previously, varieties of *Nicotiana tabacum* vary widely in number, size, shape, color, and texture of leaves, length of internodes, and color and size of flower. On the basis of leaf shape and corolla shape, Comes (1905) referred all existing forms to six primary varieties, namely, *fruticosa* Hook, *lancifolia* (W.) Comes, *virginica* (Agdh.) Comes, *brasiliensis* Comes, *havanensis* (Lag.) Comes, and *macrophylla* Schrank. Of these, *virginica* and *brasiliensis* were considered as no longer to be found in the pure state. Anastasia (1907, 1914) has proposed that the fundamental varieties be reduced to four—*havanensis*, *brasiliensis*, *virginica*, and *purpurea*. The Howards (*8*) attempted to classify the cultivated forms in India according to leaf form and length of internode, and 51 sorts were recognized. However, study of numerous crosses disclosed recombinations which exceeded the limits of the parents and showed that the derivation of a variable cultivated species cannot be traced by a classification based simply on morphology or structure.

In the early work in improvement of tobacco varieties beginning about 1900, the impression prevailed that change from one environment to another may cause a breaking up of the type. Careful experiments made later by Hasselbring (*6*), East and Hayes (1912, 1914), Honing (1915–19), David (1925), and others have shown that this is not the case. Although tobacco normally is self-fertilized, cross-pollination is sufficiently common so that seeds produced by self-fertilization may show variations in type because they came from cross-fertilized ancestry. But it is true that expression of inherited potentialities may be modified or even suppressed by environment.

It has been suggested by Christoff (1925) that three factors determine flower color in tobacco, and Setchell (*10*) and his associates (1922) concluded that at least three factors affect leaf-base characters. Lodewijks (1911) investigated an aurea or yellow-color condition observed in tobacco in Sumatra, and Allard (1919) found the aurea character in the stem of *Nicotiana rustica* to be dependent upon a single Mendelian factor recessive to green stem. Of special interest is the genetic behavior of the chlorotic stem and leaf vein and the yellowish-green color of the leaf lamina which are characteristic of the commercially important White Burley variety. Investigations by Kajanus in Sweden (1924) and Henika at the Wisconsin Agricultural Experiment Station (1932) showed that duplicate genes are involved in production of the normal green color in tobacco, and absence of both results in the Burley color. In crosses of the White Burley with normal green varieties, the F_1 was green, and segregation in F_2 approximated a ratio of 15 green: 1 yellow, the latter segregates breeding true.

Extensive studies of hybrids between varieties of *Nicotiana tabacum* have been made by Hayes (1912), Hayes, East, and Beinhart (7), and others with respect to quantitative characters susceptible of direct measurement in the field, particularly number of leaves per plant, length, breadth, and area of leaf, and height of stem. In general the first generation is intermediate and relatively uniform, while the second generation shows a continuous variety of sizes which cannot be readily separated into classes or ratios.

In an experiment with a cross of Connecticut Havana on Sumatra, selection was made in self-fertilized lines for a high number and a low number of leaves. It was found that any desired average number of leaves from about 12 to 30 could be obtained in combination with various sizes and shapes of leaf. However, in some instances selection for at least 12 years may be necessary to obtain fixed forms (*3*). These results indicate that inheritance of size is controlled by a large number of quantitative factors which produce cumulative effects.

Results of an extensive study of crosses between several tobacco varities also have been reported by Setchell, Goodspeed, and Clausen (*10*). In a study of suckering habit, Johnson, at the University of Wisconsin (1919), found this to be a purely quantitative characteristic yielding results similar to those applying to leaf size.

Reference already has been made to variation of nicotine content in tobacco and the development of low-nicotine strains. Hackbarth and V. Sengbusch (1935) suggest that such strains may be obtained in any variety of tobacco if a sufficiently large number of individuals can be examined. They find that a single fundamental factor determines the difference between high-nicotine content and the "nicotine-free" condition. However, since the plants arbitrarily designated as nicotine-free on the basis of a rough method of chemical analysis appear still to contain small quantities of the alkaloid, the genetic situation may not be as simple as indicated.

Up to the present the tobacco-breeding work pertaining to improvement in quality has had to do chiefly with visible or measurable characteristics, mainly number of leaves produced and their size, shape, and gross structural characteristics. Comparatively little of special moment has been done on inheritance of the various properties or characteristics of the cured leaf which largely determine its commercial value but which unfortunately are not readily measurable, especially in the field. Some of the practical difficulties involved in dealing with these properties have already received consideration.

Few mutations have been observed in tobacco, although little is known as to the possible occurrence of mutations involving only slight changes which would not be readily detected by inspection. Appearance of the White Burley variety in 1864 constitutes, from a practical standpoint, the outstanding example of mutation, if it is true that this was really the origin of the variety. A frequently recurring mutation is that known as "gigantism" or "indeterminate growth," referred to in the discussion of Maryland varieties of tobacco. The mammoth type is peculiar in that it continues to grow without formation of the usual terminal inflorescence when exposed to the long days of summer, but with the short days of winter or in low latitudes it flowers normally. This type of mutation was reported by Hunger in Sumatra tobacco in 1905, and it was subsequently observed in Maryland tobacco, Cuban, Havana Seed, Orinoco, Puerto Rican, and other varieties. In crosses with ordinary varieties of the normal or flowering types and

with *Nicotiana sylvestris* and *N. glutinosa*, the ordinary or flowering type usually is dominant, and probably a single gene is involved. The one-fact or ratio of 3:1 is difficult to obtain, possibly because the character is sensitive to changes in environment.

Doubling of chromosome numbers has been shown to produce larger plants in various genera of the family Solanaceae to which tobacco belongs. It occurs in jimsonweed, petunia, black nightshade, and tomato. In tobacco, Clausen and Goodspeed have described a race resulting from the cross *glutinosa* × *tabacum* which had the doubled chromosome complement and enlarged structural characters.

Goodspeed and his associates have published extensive data on the production of mutations in tobacco by irradiating buds of the terminal inflorescence with X-rays. Seven pure-breeding derivative types and seven other types not breeding true have been obtained from the progeny of a single X-rayed female gamete of *N. tabacum* (1934). Netherland East Indies investigators also have conducted similar investigations.

Existing forms of *N. rustica* have been referred by Comes (1899) to six stem types on the basis of structural characteristics, and the Howards (1910) have studied 20 forms in India which were classified on the basis of differences in length of internode and structure of inflorescence. Crosses between the various forms have served primarily to furnish additional evidence of multiple-factor inheritance.

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Appendix

TABLE 3.—*Breeding stocks possessing characteristics of special value*

Variety or strain	Commercial leaf type	Origin	Points of superiority	Remarks
Wisconsin Havana 38	Cigar binder	Wisconsin Agricultural Experiment Station, 1915.	High yield, high quality	Valuable parent stock for yield and qual ity.
Havana 142	do	Wisconsin Agricultural Experiment station, 1925.	Resistant to black root rot	Valuable parent stock. Limited acreag in Wisconsin.
No. 301	Cigar wrapper	Florida Agricultural Experiment Station, 1930.	Resistant to black shank	Major variety in Florida cigar-leaf area valuable parent stock.
Round Tip	Cigar binder and cigar wrapper.	Connecticut Agricultural Experiment Station, 1921.	High quality, root rot resistant	Widely grown in Florida prior to appear ance of black shank.
Maryland Mammoth	Maryland	Maryland Agricultural Experiment Station and U. S. Department of Agriculture, 1906.	Produces many leaves, indeterminate growth habit.	Valuable breeding stock for increasin number of leaves.
Standup Maryland Mammoth.	do	U. S. Department of Agriculture, 1933.	High yield, high quality	Superior in quality to ordinary Marylan Mammoth.
Maryland Standup Resistant.	do	U. S. Department of Agriculture, 1930.	Resistant to root rot	Limited acreage in Maryland at present
Johnson Resistant White Burley.	Burley	Wisconsin Agricultural Experiment Station, 1922.	Resistant to black root rot	Valuable parent stock. Limited acreag in Virginia an Tennessee.
Kentucky No. 5	do	Kentucky Agricultural Experiment Station, 1929.	do	Extensively planted in Kentucky.
Stand-up Burley Mammoth	do	U. S. Department of Agriculture, 1933.	Produces many leaves of upright growth, resistant to black root rot.	Only grown experimentally.
Narrowleaf and broadleaf strains of One Sucker.	One sucker	Kentucky Agricultural Experiment Station.	Reduced production of suckers	Breeding stocks for suckering habit.
Gold Dollar, strain of Jamaica (Orinoco).	Flue-cured	Coker Pedigreed Seed Co., South Carolina, 1930.	High yield, high quality	Widely grown in flue-cured areas.
Special No. 400	do	North Carolina Department of Agriculture and U. S. Department of Agriculture, 1934.	High yield, high quality, resistant to black root rot.	Limited acreage in North Carolina.
Ambalema		Puerto Rico Department of Agriculture and Commerce, 1933.	Highly resistant to mosaic	Valuable parent stock.
No. 79A		U. S. Department of Agriculture, 1935.	Moderately resistant to wilt	Do.
No. 57		do	Moderately resistant to mildew	Do.
Low-nicotine Cuban 408	Cigar filler	U. S. Department of Agriculture, 1909.	Very low in nicotine	Not grown commercially.
N. rustica, var. Brasilia		Importation from Italy, 1913	High content of nicotine	At present grown only experimentally.

TABLE 4.—*Breeding projects under way and plans for future development*

Diseases for which resistance is sought	Location of work	Type of tobacco concerned	Diseases for which resistance is sought	Location of work	Type of tobacco concerned
Black root rot	Connecticut [1]	Cigar.	Root knot	Georgia [1]	Flue-cured.
	do	Cigar (shade).		South Carolina [1]	Do.
	Massachusetts [1]	Cigar.		North Carolina [1]	Do.
	Wisconsin [1]	Do.	Black shank	Florida	Cigar.
	Maryland [1]	Maryland.		North Carolina [1]	Flue-cured.
	Kentucky	Burley.	Fusarium wilt	Kentucky	Burley.
	Tennessee [1]	Do.	Granville wilt	North Carolina [1]	Flue-cured.
	West Virginia [1]	Do.	Mildew	Georgia [1]	Do.
	North Carolina [1]	Flue-cured.		North Carolina [1]	Do.
	Virginia	Do.		South Carolina [1]	Do.
	Kentucky	Dark air-cured.	Mosaic	Maryland [1]	Maryland.
	do	Fire-cured.		Kentucky	Burley.
	Virginia	Do.		North Carolina [1]	Flue-cured.
				Wisconsin [1]	Cigar.

[1] Cooperative project between U. S. Department of Agriculture and the State indicated.

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Livestock Breeding at the Crossroads

A Foreword on the General Results of the Survey of Germ Plasm in Beef Cattle, Dual-Purpose Cattle, Sheep, Swine, and Horses [1]

IN THE belief that the time is ripe for a thorough reexamination of present methods and results in livestock breeding, this introductory article endeavors to present a summary of the general situation. Even though they are presented with a due realization of their tentative nature, some of the conclusions will be considered debatable. It is hoped, however, that they will arouse active and thoughtful interest among those most vitally concerned, scientifically and economically, in the vast livestock industry.

During 1935, in cooperation with the State agricultural experiment stations, the Department carried on surveys of germ plasm in all of the important classes of livestock and field crops. The details of the livestock surveys, both as to the information requested and the results obtained, are given in the articles on the various classes of farm animals which follow this general discussion. Specific data were requested so that any resulting catalog of superior germ plasm that might be developed would be scientifically correct.

The survey for these classes of farm livestock, however, revealed the striking but negative fact that the State agricultural experiment stations and the Department of Agriculture are interested in the art and practice of animal breeding, but that insufficient consideration is given to the subject of heredity insofar as it concerns the characters of economic value in these animals. In other words, no catalog of superior germ plasm in these classes of livestock resulted from the survey. Lack of yardsticks for measuring genetic variation in the most important economic characters, and hence lack of records of value for judging superiority, eliminated the possibility of cataloging superior material at this time.

Neither within nor between the State agricultural experiment stations and the Department of Agriculture has there been a systematic effort to develop, isolate, perpetuate, or catalog superior germ plasm. Purebreds have been firmly identified in the public mind with animals of superior merit. In the common use of the term,

[1] Many workers in the Department have contributed to this article, and much valuable historical and genetic material was supplied by J. L. Lush, head of the animal breeding subsection, Iowa State College.

however, as applied to the classes of livestock here considered, a purebred is an animal registered or eligible for registry in the official records of the association for its breed. The rules governing eligibility for registration differ somewhat for different classes and breeds of livestock. A great deal of attention has been given registered animals as such, and especially blue-ribbon winners, but there has been no corresponding amount of attention, in the case of most of the classes of livestock dealt with in this article, to finding out whether these animals really carried superior germ plasm or whether, so far as functional abilities are concerned, their germ plasm might be actually inferior to that of other animals.

Naturally, breeders and farmers look to the scientist for leadership in the development of both basic information and methods of improvement. The contributions in this direction have been very modest, and there has been little change for the better in the situation since the survey of animal-breeding projects at the State agricultural experiment stations was made by the animal-breeding committee of the National Research Council in 1927.

Are We at a Turning Point in Livestock Breeding?

THE art and practice of animal breeding is older than recorded history. The dog was domesticated far back in the Old Stone Age. Oxen, sheep, and swine were already domesticated when the New Stone Age began in Europe. Horses were being ridden at least as far back as the early Bronze Age in Europe (stirrups and bridle bits have been found in Bronze Age deposits) and perhaps much earlier in Asia. The practice of animal breeding goes back hundreds and perhaps thousands of times as far as complete written records of it.

Since the founding of the present breeds, progress has consisted largely in increasing the number of purebreds. There is evidence that this period of rapid expansion is nearing its end. What is to be the next step? Since little or no genetic effort has been made to improve the breeds themselves, progress now seems to be slow, in marked contrast with the situation in plant breeding, where efforts at improvement, as well as the spread of superior material, have been continuous and have brought notable results.

There are indications, however, that livestock breeding may be at a turning point in its long history. He would be a wise man who could say exactly what direction it will take, but at any rate there is a growing feeling that something is basically wrong in the present situation.

One thing would be agreed on by a considerable number of forward-looking breeders and experimenters—that while the methods and practices of the past have accomplished a great deal, giving us the fine breeds of livestock we have today, yet these methods and practices have taken us about as far as they can. The most we can expect to do, if we continue to follow them, is to hold the gains that have been made. Breeding in these five classes of livestock, in other words, is likely to become a frozen and static art, satisfied to stay where it is, or at best to make extremely slow progress.

It may be that this is what must happen in animal breeding. The fundamental difficulties in the way of further advance are real and great, and it may prove to be true that we have gone as far as we can genetically, at least for a long time to come, barring some unexpected development as epoch making as the discoveries of Mendel. Further progress in the livestock field may depend on other factors, such as improvements in feeding or greater knowledge of the functioning of endocrine glands in the animal organism. Too confident predictions cannot be made one way or the other. But if a blueprint for future progress cannot be made at present, there is no question about the need for a fresh appraisal and analysis. Out of such an analysis, it should be possible to develop or discover some of the conditions that will be necessary if there is to be further progress.

WHAT RETARDS PROGRESS?

The present situation in livestock breeding is the product of a complex of forces or conditions that have acted to paralyze movement toward any practical goal. They might be summed up under four general headings:

(1) The domination of standards that are incomplete and in some cases inaccurate.

(2) Lack of real yardsticks to supplement or revise existing standards.

(3) Large gaps in the knowledge of animal genetics.

(4) Certain factors that stand in the way of experimenting, including the expense of new experimentation.

Confusion Caused by Questionable Standards

Generally speaking, the questionable standards are of two kinds—esthetic or show points, and pedigrees as these are commonly used.

In the case of most of the classes of animals here dealt with, breeds have become well established through generations of effort, almost entirely on the part of private breeders, many of whom were geniuses when it came to dealing with animals. The registered animals that constitute these breeds are equivalent to trade-marked articles. They are produced in accordance with specifications as to type, conformation, color, and what not. Many of these specifications are equivalent to trade marks, and the trade marks may or may not stand for real values in a given case.

Almost every breed, for example, has an official description of its ideal, which is not primarily based on biological values applicable to a breed-improvement program. Insofar as such direct attention and effort to something that has no scientific basis, they may be called artificial devices. There is no question about the value of the show ring for bringing livestock men together in a common meeting place to discuss their problems and interests; but by descriptions and pictures, farmers and breeders are easily led to believe that some practices have a scientific basis that does not exist.

It is not that esthetic show points are wrong in themselves. In the case of Pomeranian dogs, for example, they are useful because the sole object is to produce an animal with a certain special and characteristic appearance valued by fanciers. A beef steer or a hog, however, is not the same kind of animal as a dog, and when the

breeder of farm livestock concentrates effort on fancy points, and exaggerates their importance, he multiplies the goals he desires to attain and they become so complex, and there are so many things to take into account, that really fundamental considerations get scant attention. As a result, improvement is retarded or stopped.

Emphasis on show points, of course, has not by any means been confined to livestock men. In 1918 Erwin Hopt, writing in the annual report of the Nebraska Corn Improvers' Association, had this to say about some practices of the earlier corn shows:

> No point seemed to be too finespun in judging corn. Judges looking grave and wise as owls stood ponderingly over exhibits of corn, settling such momentous questions as to whether this exhibit containing two ears with somewhat "pinched in" butts was or was not superior to another exhibit in which was an ear with an exposure of cob at the tip of exactly three sixty-fourths of an inch. Meanwhile, wondering crowds of awe-stricken people stood open-mouthed, watching the judges make their epoch-making decisions. I am afraid that * * * I have been one of the pious frauds who were presumed to know by some delicate process of divination just which ear or exhibit was better than another. The whole thing would have been ludicrous if it had not been so pathetic. * * *
>
> [A] notice * * * should be displayed in a prominent place over the corn show [reading] something like this: "This is all a joke, folks. Don't take the thing too seriously. It should be distinctly understood by all visitors that this is just a little game we boys have gotten up among ourselves. It has no relation to utility. Our prize-winning exhibits, upon which we so pride ourselves, mean nothing. They will not yield any more than other ears * * *.
>
> "In other words, it would not be so bad if we took the public into our confidence and would frankly acknowledge that we had deliberately set up an arbitrary and artificial standard of beauty and that all this hurrah and hullabaloo had little or no relation to what farmers are really interested in, namely, bushels of shelled corn per acre, profitably raised."

In the case of some classes of livestock, these show points have developed out of the emphasis on the show ring as almost the only place provided for measuring merit.

The idea of pure breeding is ancient, as may be seen from the extravagant claims about their own purity of descent embodied in the racial mythology of so many tribes and peoples. Casual references imply that this idea was extended to their livestock.[2]

In the country of their origin, the pure breeds were but slightly set apart from the common stock of their districts, but when they were first introduced into a foreign country they were usually so distinctly different from the native stock that the gap between purebred and other stock was wide. Hence the emphasis on purity of breeding has naturally been greater in most importing lands than in most exporting lands, except that, as a breed developed an important export market, the demands of the customers—as of American and Argentine buyers of Shorthorns from Britain—often widened the gap between registered and nonpedigree or short-pedigree stock, even in their native lands. In a day of expanding numbers of registered animals and more emphasis on the difference between them and other stock than on the differences between various recognized breeds, efforts at improving the average merit of the registered animals were usually less immediately important than efforts at breed promotion and still further extolling the merits of the breeds as such.

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[2] However, the practice of cross-breeding was also explicitly recommended at times, and in the absence of complete pedigrees, some outcrossing doubtless took place even where the ideal was pure breeding. It is probably correct to say that the general picture of animal-breeding systems among ancient peoples was pure breeding with occasional crosses of distinct races. Yet there must also have been periods when the cross-breeding was so frequent that it more than counteracted the tendency of pure breeding to create uniform local races distinct from each other.

Breeds Developed for the Same Purpose are Arbitrary Division Fences

But the fact is that in many cases the outstanding points of difference between many breeds of meat-producing animals are extremely superficial. For instance, a Hereford and a Shorthorn steer are easily identified on foot for a well-known reason, but he would be a rare individual who would care to stake his reputation on telling them apart as they hang in the cooler as well-finished sides of beef. They may have come from equally fertile strains; they may have made equally efficient gains, and the carcasses may be indistinguishable. Yet the pedigrees of these two steers are separate and their ancestors have lived for over a century in an animal society where mixing of the two germ plasms constitutes a breach of etiquette punishable by

FIGURE 1.—Third-cross calves from the well-known grading-up demonstration with Shorthorn cattle at Sni-a-Bar Farms, Grain Valley, Mo. Results there indicate that after the third or fourth cross of registered sires on grade cows, only exceptional sires can bring about further improvement.

condemnation to the butcher's block. A similar situation exists among swine, where in many cases it is impossible to identify the breed once the head and bristles are off. Have breeders accumulated these combinations of hereditary material under the banners of the various breed societies without realizing the underlying similarities of the breeds? Whether they have or not, it is clear from our knowledge of history and our realization of the present situation that in the biological field the breeds, particularly those developed for the same purpose, are often arbitrary division fences maintained to please certain groups of breeders.

The situation is somewhat more complex than this picture indicates. There are other factors that interfere with any steady progress toward livestock improvement. For one thing, ideals change from time to time for the same class of animals and from one locality to another.

Again, confusion arises from the fact that the current show-ring ideal is not necessarily the same as that followed by the breeder for a number of reasons, the most important of which is probably economic pressure. There may be almost a right-about-face in ideals at different periods, as when the show ring called for small Poland China swine during the first decade of this century and later swung to the other extreme of size and length, while the farmer's ideal remained somewhat intermediate. Doubtless there is some justification at times for such discrepancies, but they are often carried too far merely to justify breed peculiarities and thus actually impede progress by decreasing the intensity of selection for really important traits.

Another example of divergence between show-ring and farmer ideals was the show-ring demand for a ton horse in the draft breeds at a time when the market demand was for a horse weighing around 1,600 pounds. The reason for this difference was the belief that with the kind and size of mares the farmers possessed, it would take

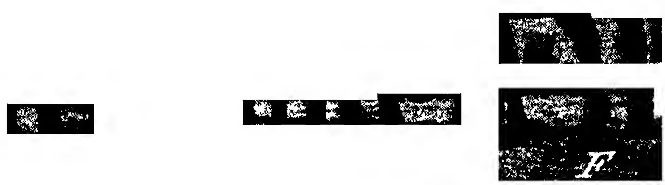


FIGURE 2.—A show-ring champion sire and his offspring of show-ring champions, the Percheron stallion Laet and his get: *A*, Butler, champion stallion bred in Ohio; *B*, Perfect, first filly futurity and reserve grand champion; *C*, Hesitation, first stallion futurity and reserve junior champion; *D*, Jerome, reserve grand champion stallion; *E*, Couceorous, reserve senior champion mare; *F*, Laet, grand champion stallion.

a ton stallion to sire 1,600-pound mares or geldings. In many cases, too, the shortcomings of show-ring ideals concern important characters such as the length of wool on sheep, which cannot be accurately evaluated when the degree of trimming and the date of the previous shearing are unknown to the judge.

The net result of all this has been a tendency to lead livestock breeders farther away from a scientific approach than they were when modern animal-breeding practices took general form in Great Britain in the late 1700's and early 1800's.

Pedigrees Give a False Sense of Security

The second point mentioned under questionable standards concerns pedigrees. Actually, this is not the second but the first requisite in the case of registered animals. Unless an animal has a pedigree that entitles it to registration in the records of the breed association, it cannot be used by the leading breeders. Pedigreed animals are considered the bluebloods among livestock.

Of course, the pedigree is nothing new. Some use of pedigrees began long ago, as witnessed by ancient proverbs in nearly every language, and by human genealogies such as those in Genesis or in ancient Hindu writings. However, these may have been used more to settle legal questions, such as the inheritance of property, than for biological reasons. The Arabs used pedigrees extensively in their horse breeding, but there seems to be no definite record of what they did with them in actually deciding how to mate horses. The systematic recording of complete pedigrees for a whole breed is a comparatively modern development, the first herdbook of that kind having been published in 1822 for Shorthorns in Great Britain.

When the breeds were small in numbers and the breeders few, only private herdbooks were in use. Indeed, some early breeders objected to telling a customer the pedigree of an animal, believing that the method of breeding was a trade secret which would lose its cash value if others learned it and imitated it. However, in the case of breeds whose numbers became so large that no breeder could know the pedigrees even of all the sires, the breeders felt the need of centralized records. This was especially the case when there was a strong export market. In such cases, before a herdbook society had been formed to record pedigrees, unscrupulous dealers often sold for export any animals they could persuade the customer to take and gave whatever pedigrees would best please him.

It was largely to remedy this situation and to preserve for breeders whatever monopoly value there might be in the possession of the limited number of animals eligible for registry that the first herdbook, The Coates Herdbook for Shorthorn Cattle, was organized. There had been one earlier herdbook, The General Stud Book for Thoroughbred Horses, but it was planned mainly to record the pedigrees of the winners of races each year; it was a kind of advanced registry for special performers rather than a list of the pedigrees of an entire breed. Other breeders, especially those who had much export trade, organized herdbooks somewhat after the Shorthorn model, slowly at first—only a few herdbooks were in existence before 1870—but rapidly in the decades just before 1900.

Again, as in the case of esthetic standards, there is nothing wrong with pedigrees in themselves. They are an indispensable tool of the breeder, since the real concern of breeding is the passing on of heritable factors from one generation to the next. The trouble with pedigrees in the case of registered animals is that they have remained a heritage from the past, inadequate from the modern scientific standpoint; but at the same time they gave a false sense of security. Very often the usual type of pedigree contains little but the names and identification numbers of ancestors, and not even that much about collateral relatives. In such cases it is only a meaningless genealogical jumble. Before it can even begin to be adequate as part of the basis for breeding, it is necessary to find out from other sources how superior or inferior these ancestors were. Again, it is often the case that the items recorded about each ancestor are only the more favorable ones, selected to impress the reader. Usually he cannot guess very closely how much bias was thus introduced. Yet these pedigrees are used as though they were solid indications of merit.

Little attention was given to improving farm animals in the United States during the pioneering stage, since other things incident to subduing a strange land were naturally more important. The first animals brought over usually were stock that came from the same localities as the colonists themselves, but no definite record of individual pedigrees was kept. When the pioneering stage ended, attention was given to improving the animals both through developing new local breeds and through importing breeds already developed in other lands. Local breeds were developed in regions where the conditions demanded new types that could not be found elsewhere.

Thus were developed the Morgan horse for general utility on the small farms in the hilly areas inland from the Atlantic coast; the American saddle horse for riding in the hilly areas of the Middle

FIGURE 3.—A contrast in beef: 2,300-pound 5-year old steer, Texas Longhorn, and prime baby beef. This illustrates the extent to which market demand and consumer preference as well as environment may influence the final expression of the animal's inheritance.

States, from Virginia to Missouri; the Standardbred horse for rapid transportation of light loads in areas where roads were improved enough for light vehicles; the Vermont Merino in the hilly parts of New England, when the premium on fineness of wool was high and Australia had not yet come to the front as an important source of fine wools; the Corn Belt breeds of swine as a means of turning unprecedented surpluses of grain into a more marketable form; the adaptation of the Hereford breed from the original imported type to one better suited to utilize scanty and often highly seasonal forage resources.

It is evident, then, that the breeds did not actually originate as fancy animals but were developed out of practical needs. In the early days in England, for instance, the ideal steer at first was an animal big enough and powerful enough to make a good draft ox.

With the passing of draft oxen, this ideal changed. What was needed then was a smaller animal that would utilize feed more economically, lay on meat of better quality, and dress with less waste in the slaughterhouse. That ideal in turn was met. In each case, the breed developed was a useful animal of better-than-average merit, or it would not have survived.

But in general each breed had certain easily identified characteristics of color or form or both, and men naturally associated these characteristics with merit and sought animals that would conform to them as closely as possible. This point is well illustrated by the preference frequently shown by some Hereford breeders for a certain shade of color merely because an outstanding sire possessed that shade, though

THE methods and practices of the past have accomplished a great deal, giving us the fine breeds of livestock we have today, but these methods and practices have taken us about so far as they can, and the most we can expect to do if we continue to follow them, is to hold the gains that have been made. Breeding in these classes of livestock, in other words, is likely to become a frozen and static art. This is in marked contrast with the situation in plant breeding. There are indications, however, that livestock breeding may be at a turning point in its long history. He would be a wise man who would say exactly what direction it will take, but there is a growing feeling that something is basically wrong in the present situation. If a blueprint for future progress cannot be made at present, there is no question about the need for a fresh appraisal and analysis, out of which it should be possible to develop the main outlines of a program for further improvement.

there is no satisfactory evidence as yet that this color in Herefords has any association with other qualities. There is naturally a tendency to remember the color of an exceptional sire and to forget the poor sires that had the same color. Similarly, if a man has good luck on a day when he happens to be carrying a rabbit's foot in his pocket, he may associate the good luck with the rabbit's foot and insist on carrying one forever after. He forgets the days when he was unlucky in spite of the rabbit's foot, and he has no accurate way of measuring and standardizing conditions that might bring him good luck with more certainty.

Thus the more superficial standards have hung on stubbornly, and better ones have not been developed to replace them. Criteria

are lacking both for livestock products and for the animals themselves. We do not, for example, have accurate standards for judging the quality of meats, though progress is being made in that direction. We do not know how to tell with any accuracy whether an animal is an efficient producer of high-quality meat except by the slow and expensive individual feeding test. Otherwise, about the best we can do is to make a rough guess based on conformation. How accurate this guess is likely to be may be judged from a single example in another field. Dr. Gowen, of the Maine Agricultural Experiment Station, found that a 7-day test was about twice as accurate an indication of a cow's productive capacity for the year as scoring by the most expert judges, drawing on the garnered wisdom of the ages to tell from the cow's looks what she would produce.

It is obvious that this lack of accurate yardsticks is a major handicap in breeding.

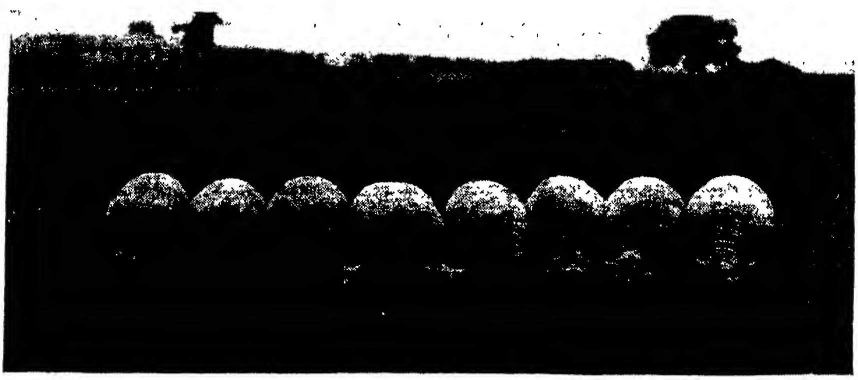


FIGURE 4.—Yearling Southdown ewes in the Government's flock at the National Agricultural Research Center, Beltsville, Md. These ewes show remarkable uniformity and are distinguishable from one another only by the closest observation. They are closely related on their dam's side and six of the group are by the same sire.

Gaps in Genetic Knowledge

For many reasons, not as much is known about genetics in the case of animals as in the case of plants. It is generally considered that the animal is a more complex organism than the plant. With the larger animals, the rate of reproduction is much less rapid than with plants; the numbers the geneticist has to work with are much smaller; the effects of environment are more difficult to separate from the effects of inheritance; and self-fertilization, which simplifies the work in the case of many plants, is out of the picture.

A few characters have been pinned to definite factors, but they are almost exclusively characters that have no practical significance from the standpoint of performance—coat colors in horses and cattle, for example, and plumage colors in poultry. (In the case of fur-bearing animals, however, coat colors are characters of great economic importance.) Even though there is little experimental evidence connecting any definite genetic factors with productiveness, fertility, rate and economy of gain, or physical vigor, it has been demonstrated that these characters are affected by inheritance and subject to manipulation by breeding methods.

Productiveness, fertility, and vigor are characters of profound biological significance, affected by many things in the make-up and

the environment of an animal. Moreover, they are almost certainly the result of many genetic factors closely interacting, and this makes the problem of analysis extremely complex even when the factors are known, which is rarely if ever the case. Suppose, for example, that there are 10 dominant factors, *A*, *B*, *C*, *D*, *E*, *F*, *G*, *H*, *I*, and *J*—to take an imaginary case—that affect production favorably, while the 10 contrasting factors, *a*, *b*, *c*, *d*, *e*, etc., affect it unfavorably. These 10 pairs of factors can come together in nearly 60,000 different combinations.[3] The breeder would have a very difficult time indeed finding out what had happened in a given instance. This emphasizes the need of casting off all useless procedures and false standards that might make it harder to reach the goal of superiority in livestock breeding.

The lack of genetic knowledge puts the scientist in much the same position as an aviator in a fog who knows exactly where he wants to go, but has inadequate instruments to guide him. Just as every improvement in instruments makes the way through the fog a little easier and safer for any make of airplane, so will advance in our understanding of animal inheritance enable the breeder of any breed to proceed more safely and efficiently.

Hesitation in Experimenting

The chief obstacles in the way of extensive experimenting that might bring results in the livestock field are usually considered to be the high cost per unit and the slow rate of reproduction of the larger animals. The professional breeder hesitates to take chances by departing from known methods when he feels that results are by no means certain, and that he runs the risk of losing everything he has gained. In plant breeding there is greater readiness to experiment because new strains can be tried out in a small way, results are known fairly quickly, and there need be no great loss in case of failure. Readiness to experiment is in itself one of the chief factors making for progress in scientific work.

Yet so far as the scientist is concerned, these are perhaps not the decisive reasons why practically no research has been conducted on the role of inheritance in the expression of such things as meat characters, for example. It is the indefiniteness of the characters themselves, changes in popular demand, and the inability of the investigator to control the forces affecting development that have prevented experimentation. The slowness of reproduction and the high cost of cattle did not stand in the way of determining the mode of inheritance of red and black coat colors in Aberdeen-Angus cattle so definitely that control by the breeder is as nearly absolute as it can be for any inherited character.

A BRIEF EXCURSION INTO GENETIC HISTORY

These are some of the factors, then, that have tended to make breeding what it is in the case of certain classes of livestock. Yet even the negative aspects of the situation give some ground for optimism. The lack of knowledge at many points at least makes it impossible to predict certain failure for a given line of experimenting. But the lack of knowledge is by no means complete. Breeders are in a far

[3] 3^n = the number of genotypes in the F_2 generation, where n is the number of pairs of factors involved. In this case, 3^{10} = 59,049.

better position than were the pioneers who founded the dominant breeds of today. The latter could proceed only by trial and error, and the results they secured were more or less a complete mystery.

The chief contributions so far made by genetic science to animal breeding are explanations of facts or processes that were already known but were puzzling. Showing how an apparent chaos of contradictions was really the natural result of orderly laws is an intangible contribution, but it has been important in dispelling superstition and enabling breeders to concentrate with more success on effective methods. The laws of heredity are now well enough known so that new breeding practices more effective than the older empirical ones have begun to be used. This is particularly true with some of the refinements of progeny testing and some of the combinations of selection with inbreeding systems.

Mendel's big service was in explaining why identical pedigrees need not mean identical heredity—a thing that hitherto had been puzzling. Also, his discoveries freed the breeder from the belief—so strongly held by Darwin—that any genuinely new inheritance would be lost if it were not at once firmly seized by selection. It is no longer considered necessary, as Darwin and all other believers in "blending" inheritance thought it was, to pay much attention to genuinely new inheritance in the form of mutations or sudden changes in germ plasm. Mutations do occur, but so far as is now known they are exceedingly rare and frequently harmful, so that they constitute only a very minor obstacle against which the breeder must struggle. Rarely, mutations which are advantageous from the very start occur, but these usually have only small effects. The mechanism discovered by Mendel is one that preserves an almost infinite store of individual variability within any large interbreeding population but has no inherent tendency to change the averages of the population unless selection in one direction is also practiced, or unless the population is so small—as in inbreeding systems—that the laws of chance permit the population average to wander over a wide range.

Around the beginning of the present century a number of scientists, among whom the most prominent were Weismann in pre-Mendelian days and Johanssen after Mendelism was rediscovered, made fairly clear the distinction between an animal's outward appearance or performance and its real heredity or breeding value—its "germ plasm" in the philosophical language of Weismann, or its "genotype" in the more precisely mechanistic writings of Johanssen. This, too, was not a new idea to practical breeders, but it began to explain in terms of scientific law commonly observed facts that hitherto had appeared capricious and chaotically unrelated.

The solution of the inbreeding problem is probably the major contribution of the second decade of genetics to the practical art of plant and animal improvement. A number of geneticists, mostly American, have had a part in clarifying the principles and consequences of inbreeding. Among them should be mentioned Shull, East, Jennings, King, Jones, and Wright. The work of explaining inbreeding was fairly well completed in 1921, and new practical methods of plant breeding—especially of corn breeding—based on that knowledge were already in operation. Wright has widely generalized the knowledge of inbreeding since then, especially irregular inbreeding, which is usually the only kind encountered in livestock pedigrees. Some practical applications to animal breeding are

already beginning to come, and these are discussed in the articles dealing with separate classes of livestock.

The consequences of breeding systems that involve some combination of selection with inbreeding and outbreeding and assortative mating are beginning to be understood, largely as a result of the studies of Wright, Fisher, and Haldane. These studies have explained many hitherto puzzling observations of breeders—for example, the usual effectiveness of selection in getting a herd average to approach an ideal, especially when first practiced, but its usual ineffectiveness—unless accompanied by inbreeding—in genuinely fixing that ideal.

HOW CAN WE BREAK THE JAM?

The knowledge of breeding systems has gone far enough so that a fair beginning can now be made at drawing practically useful measures and working plans for breed improvement beyond what was possible with the former empirical rules, though a considerable amount of further study and experimenting is necessary to clarify the details.

The geneticist is not able to map the factors or genes of an animal, as many of the genes in the pomace fly have been mapped, for example; but knowing in considerable detail how inheritance operates he is able in some cases to act *as if* he knew the genes themselves. This acting *as if* we knew is one of the most fruitful methods of science. Corn breeders do not know the factors that control yield, date of maturity, height of stalk, disease resistance, and similar important economic characters. But they do not hesitate to act as if they knew what the factors were, and thereby they have developed strains valuable in these respects. Undoubtedly these strains do carry the factors, whatever they may be. The corn breeder does not say that he has to wait until they are cataloged before he can use them.

Thus it seems possible to lay down the broad outlines of a program that might break the jam. This program would have four main points, corresponding to the four factors that now prevent further progress.

Point 1. Getting Rid of Standards Based on False Methods of Evaluating Merit

Everything that is known about genetics indicates that it is vital to concentrate on as small a number of objectives as possible. The indispensable objectives in livestock breeding are production, reproduction, and vigor in the broadest sense. They are sufficiently difficult to attain without adding others that have no bearing on fundamental values. Every unnecessary factor introduced for color, conformation, or what not makes the problem that much harder. For example, four genes can combine in the F_2 or segregating generation in enough different ways to produce 81 genetically different offspring (genotypes), and ordinarily the number of individuals that would have to be examined to work out the mode of inheritance would be at least 1,000. It is evident, then, that breeding for unnecessary details adds not only to the difficulty of the work but to its cost.

Point 2. Developing Practical Yardsticks

The process of getting down to essentials can be only partial, however, until we develop better criteria for measuring and evaluating

animals from the standpoint of efficiency of feed utilization and apply them on a much wider scale than at present. Then must follow—notably in the case of meats and of wool—the development of quicker and more certain methods for analyzing the product itself. Scientists have not been idle in this field, and research here must continue.

Testing for advanced registry in the case of dairy cows is an example of the use of practical criteria in judging animals. Another example is the use of speed records in breeding horses. In both cases, the use of these practical yardsticks has apparently brought results. The progeny test, discussed later in this article and in each of the articles dealing with a specific class of livestock, should be included among the indispensable procedures wherever it is practicable. This applies also to sound pedigree records. For example, no direct measure of the egg-production value of a cock is possible, but his value can be judged from the production records of his progeny.

Point 3. Carrying on Breeding Experiments

Without extensive experimentation, all discussion of breeding policies must remain theoretical. The scientist can readily formulate theories, but unless they are put to practical test, they have only an academic value. It has already been pointed out that, in the case of the larger animals, breeding experiments are likely to be costly and to consume a great deal of time. In addition, they demand scientific training and ability, and the economic results are by no means certain. For all these reasons, it seems unlikely that adequate experimenting will be done by private breeders who are compelled to stick closely to operations that are profitable. A few wealthy men might undertake this kind of work, but accidents happen to private fortunes, men change their minds, and successors may not have the same ideals, and, under these conditions, there is no assurance of continuity. It looks as if this function must be performed by governmental agencies, or by foundations or institutions of one kind or another, for the good of the livestock industry as a whole.

Point 4. Continuing Genetic Research

Study of genetic factors in animals must of course be continued, in combination with research in animal physiology and embryology. Real progress in livestock breeding may depend on getting greater genetic knowledge than we now have more than on any other one thing. There is an interaction, however, between practical experimenting and basic research—each complements and contributes to the other. If, for example, genes are to be studied, they must be taken up one by one; and this can best be done as part of a program of practical experimenting.

In other words, the problem of livestock breeding cannot well be separated into watertight compartments of theory and practice. It must be considered as a whole. But for that matter, breeding itself is not a watertight compartment. It is only part of the whole biology of the animal organism.

The Real Purpose of Inbreeding

The third point above, carrying on breeding experiments, calls for further discussion. No detailed experimental program can be laid down here, but present knowledge indicates that it should be based on inbreeding as the first step to develop distinct strains or families whose characteristics may be accurately known and studied.

In recent years, some workers have taken an experimental approach toward inbreeding, especially in the case of swine, and have secured some extremely interesting results. These efforts are discussed in the articles on the different classes of livestock.

Inbreeding is the surest and quickest way to produce homozygous combinations of genes, that is, factors that are the same from both parents so that the offspring gets a double dose of the same thing—an *ABC* from the mother and an *ABC* from the father, for example, not an *ABC* from one and an *aBc* from the other. It need hardly be said that some of the genes thus concentrated may be factors for either desirable or undesirable traits. Suppose—again to take an imaginary example—that *A*, *B*, and *C* are all desirable, while *a*, *b*, and *c* are undesirable. By inbreeding, we isolate a family with the combination *aaBBCC*. The double dose of *a* might show up as lack of fertility, for instance, whereas if the progeny had had an *A* from one parent and an *a* from the other—that is, a heterozygous combination—the *A* might mask or dominate the *a* and the lack of fertility would not show up. This fixing of some unfortunate combinations of genes, in fact, often happens when cross-fertilized organisms are intensely inbred. An actual instance is given in the record of Bates' Duchesses. These were closely inbred, and "a low level of fertility seems to have become fixed and to have doomed the efforts to maintain a 'pure' Duchess strain after Bates' death." The low fertility, however, was considered to be an advantage. It made the stock scarcer and therefore higher priced.

It was one thing to avoid inbreeding, however, when the causes of the evil results were unknown. Today the causes are well enough understood so that there is a possibility of controlling results. or discovering and avoiding the danger line.

One method of control is the use of selection. It is true that intense inbreeding may bring defects to light so fast that selection cannot discard all the defectives. In that case it may be necessary to modify the intensity of the inbreeding, which means proceeding more slowly.[4] But on the other hand, one of the major uses of inbreeding is to bring defects to light rapidly in whole families. By such segregation, it is possible to study the defects and perhaps discover their inheritance. More important from the practical standpoint, however, is the fact that selection can then get at the defects in whole families as well as in individuals and throw out the families that carry them. So long as selection is practiced only between indi-

[4] The intensity of steady inbreeding systems can be measured closely enough for most practical purposes by Wright's formula (1931) that in a population of limited size closed to outside blood and containing many more breeding females than breeding males, the fraction of the existing heterozygosis lost per generation because of the inbreeding inevitable from the limited size of the population is about one-eighth *M*, where *M* is the effective number of breeding males used each generation. The "effective number" will be smaller than the actual number if the sires are not used equally and if very unequal portions of the descendants of the different sires are saved. Application of this formula gives the following percentages of the genes heterozygous in each generation which will probably become homozygous the next generation in populations of various sizes closed to outside blood: 50 percent under self-fertilization (impossible in farm animals, of course); 19 percent under steady brother-sister mating (uneconomic with farm animals on account of the large number of males required); 11 percent in a one-sire herd; 6 percent in a two-sire herd; 4 percent in a three-sire herd; 3 percent in a four-sire herd; 2½ percent in a five-sire herd; and 2 percent in a six-sire herd.

viduals, there is no guarantee that a fine animal may not, in his heredity, carry undesirable genes whose effects will appear unexpectedly in future generations. In this sense, inbreeding may be considered as a sort of truth detector, or a sounding apparatus to discover what is under the surface.

But selection, and modifications in intensity, are not the only means of controlling the undesirable characters brought to light by inbreeding. Lines that were undesirable would not matter to the plant breeder. He would merely throw them away. The animal breeder is forced to be more saving of his material. When an inbred line goes bad, he resorts to occasional outbreeding to correct the defects, or to bring in other desirable characters. If two inbred families with different defects are crossed, it frequently happens that the immediate result in the offspring is an increase in the intensity of desirable traits, such as vigor and productiveness, not only above that of the parents, but above the average of populations of exceptional merit not affected by inbreeding. Thus at one stroke previous losses are wiped out and

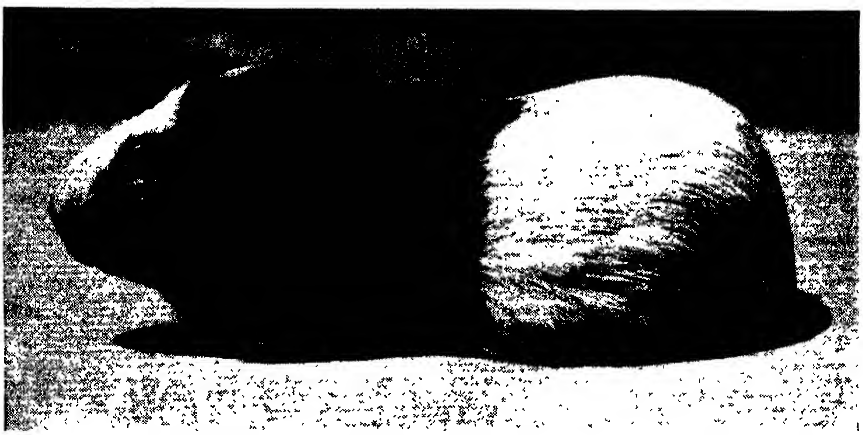


FIGURE 5.—The guinea pig has played an important role in animal breeding, especially in relation to the hereditary basis for such complex traits as fecundity, rate of gain, body size, resistance to disease, and certain anatomical abnormalities. Much time and expense have been saved through use of these little animals as material for investigating breeding problems of far-reaching importance to livestock.

there is a net gain besides. The nature of the mechanism that brings this about is now well understood, even though the genes involved cannot be identified; essentially it consists in breaking up undesirable gene combinations that have become fixed and introducing compensating or modifying factors from another family, though that family itself may have undesirable characteristics.

The full effect of such outbreeding is apparent in the first or at most the second generation. Thereafter the inbreeding should be continued again, to act as a rachet mechanism and hold the gains made—until another shot of outside genes is necessary.

Inbreeding may be thought of as a means to encourage distinct families to wander from the breed average, some becoming superior and others inferior in many different ways. Outbreeding is a tool for suddenly leveling and destroying these family differences and starting over again with what amounts to a new family. The two in combination are at the heart of modern plant breeding. In this field they have been, and continue to be, the most effective means yet dis-

covered for achieving results and attaining the maximum certainty of control. Geneticists are well aware that theoretically they should give comparable results in the case of animals.

Admittedly, the more intensive forms of inbreeding, in the case of animals, require facilities and a procedure that make them unsuitable for general use, at least until much more is known about possibilities, limitations, and necessary precautions; though in the modified form known as line breeding, inbreeding is used in practical operations, combined with outbreeding.

Bakewell used inbreeding as a valuable tool. When his success encouraged others to establish flocks and herds of his breeding, the larger numbers available within each breed reduced to an almost negligible level the inbreeding consequent upon pure breeding. The very popularity of a breed, therefore, usually brought the inbreeding almost to an end, leaving selection as the only method by which the breed was improved or changed after the formative period when it existed in only one or a very few herds.

This in general has been the breeding history of most pure breeds, especially those of British origin. Many of Bakewell's followers used his methods on the native stock of their own regions. What proportion of them failed we have no way of knowing. Those who succeeded went through a formative period of selecting and inbreeding animals while their numbers were small enough so that the inbreeding was a force of some magnitude. As the new breeds became recognized as successful and were expanded in numbers, the inbreeding was generally dropped, except here and there when some stubborn individuals sought to breed a "pure family" within a breed, as in the case of the Bates-bred "pure Duchess" family of Shorthorns already mentioned, or the "straight Scotch" Shorthorns, or the "straight bred" Anxiety 4th Herefords of more recent years.

There are cases in practical breeding history where the occasional use of parent-offspring matings for one or two generations has been conspicuously successful. The extensive use of the Shorthorn bull, Favorite, on his daughters in the Colling herds in the early history of the breed is probably the most conspicuous, but there are many others less extensive, such as the use of the Aberdeen-Angus bull, Earl Marshall, on several of his daughters. Breeders have been particularly apt to resort to the method when the parent appeared to be of such extraordinary merit that it would be years before an animal equally good could be found to replace it.[5]

Inbreeding Experiments with Guinea Pigs

Wright's work in inbreeding guinea pigs at the National Agricultural Research Center at Beltsville, Md., is now a classic example, and as already indicated, some work has also been done with larger animals. The Beltsville experiment has been carried on by the Bureau of Animal Industry for 25 years and has involved records of over 100,000 guinea pigs. These include the records of 23 separate families, each descended from an original pair exclusively by matings of brother with sister, without selection; a control stock in which inbreeding has been carefully avoided; and crosses among the inbred

[5] Inbreeding less intense than brother × sister and parent × offspring matings is slight in effect. Thus, when sire and dam have two grandparents in common—as human first cousins do—the offspring will probably have lost about one-sixteenth of the heterozygosis which the grandparents had. If the mates have only one grandparent in common, the corresponding fraction is about one thirty-second.

families. Some of the inbred families have been carried through 35 generations of continuous brother × sister matings. It should be kept in mind, however, that the experiments with guinea pigs differ from practical procedure with large animals in that one male was mated to one female instead of to many females.

On the average there has been a decline in all elements of vigor, but at the same time a conspicuous differentiation among the families. Although the most obvious differentiation concerns such characteristics as color, number of toes, and a tendency toward production of particular types of abnormalities, there are also significant family differences in all the elements of vigor and reproductive ability. These elements of vigor have proved to be inherited independently of each other, and each family has come to be characterized by a particular combination of traits, usually involving strength in some respects and weakness in others. Crosses between different inbred families have resulted in a marked improvement of both parental stocks in every respect. A certain portion of the increase in vigor of the first cross between the inbred families is maintained on resuming random mating, the proportion depending on the number of lines involved in crossing.

The relation of this experiment to a livestock-breeding program is summarized in Department Bulletin 1121, entitled "The Effects of Inbreeding and Cross-breeding on Guinea Pigs." In this bulletin, it is pointed out that, because of the large and confusing effect of environment on traits of economic importance—

> progress by ordinary selection of individuals would be very slow or nil. A single unfortunate selection of a sire, good as an individual, but inferior in heredity, is likely at any time to undo all past progress. On the other hand, by starting a large number of inbred lines, important hereditary differences in these respects are brought clearly to light and fixed. Crosses among these lines ought to give a full recovery of whatever vigor has been lost by inbreeding, and particular crosses may safely be expected to show a combination of desired characters distinctly superior to the original stock. Thus a cross-bred stock can be developed which can be maintained at a higher level than the original stock, a level which could not have been reached by selection alone. Further improvement is to be sought in a repetition of the process—the isolation of new inbred strains from the improved cross-bred stock, followed ultimately by crossing and selection of the best crosses for the foundation of the new stock.

On the whole, however, experimental work of this sort with large animals has been tentative, halting, and partial, due to the practical drawbacks previously mentioned—cost, numbers, time, lack of knowledge, and uncertainty as to results.

As the situation now stands, however, more extensive work on this line by experimenters seems to be a logical step. This is not to say that the homozygosis or "purity" for certain characters achieved by inbreeding should be confused with merit and made an end in itself. Homozygosis is not the final goal. Merit is the goal, and getting animals pure or homozygous for certain important characters is one of the methods for achieving it. Theoretical genetics shows why it is a potent means, and practical plant breeding shows how it works out in that field.

Crossing of Unrelated Inbred Strains

This is a method used in plant breeding, and in certain respects in practical livestock operations on the farm. Essentially, it consists in maintaining distinct, widely divergent lines of known composition

as breeding stock, then crossing these lines and using the progeny or F_1 generation for market or for production. As breeders have long known, the first generation of crosses between certain breeds has marked hybrid vigor or heterosis. Too little effort has been made to use this hybrid vigor as part of a regular breeding system in the livestock field, with the notable exception of mules and some work with sheep and swine. Logically, the method should have considerable value, and its possibilities should be systematically explored. When the relation between homozygosis and merit in animals is better understood, it may be that the real goal will turn out to be controlled heterosis.

FIGURE 6.—Duroc-Jersey-Yorkshire cross-bred litter, produced in Indiana. The litter weighed 4,080 pounds, or more than 2 tons, at 6 months. Ton-litter contests sponsored by many States produced some surprising results. An Indiana sow in four consecutive litters farrowed a total of 54 pigs and raised 53 of them. Six gilts from her first litter raised a total of 63 pigs for their first litters.

Ways of Improving the Inheritance of Farm Animals

QUITE aside from the question of research and experiment, the livestock man, whether producer or breeder, is interested in methods immediately applicable to the improvement of his own animals. This subject is discussed in books on practical genetics, in Federal and State bulletins, in technical journals, in courses in the agricultural schools and colleges, and in farm gatherings. Nevertheless it may be well to repeat here some of the preliminary considerations that must be kept in mind in practical livestock breeding, if only for the reason that progress does not lie entirely in the hands of the experimenter and the professional. The farmer whose production is confined to plant crops may have little direct concern with breeding; he may buy all his seed from others who specialize in seed production. But the livestock farmer, in most cases, is very directly concerned in animal breeding, since it is the necessary first step in production. Any advance in livestock breeding, then, must rest on a broader base than in the case of plants. It must be understood, accepted, and used by large numbers of farmers as part of their everyday routine. Incidentally, in carrying on breeding operations intelligently, the farmer may make definite contributions and achieve worth-while results even though he does not have theoretical knowledge. This is exactly what was done by the early breeders.

The methods now available for improving the inheritance of farm animals are fundamentally the same as those in use before there was any science of genetics, but they are better understood and can be used to better advantage. A beginning has been made at measuring what each breeding method will do under certain circumstances, and more experience with such quantitative measures may work as much change in breeding methods as the use of definite weights did in transforming ancient alchemy and household chemistry into modern scientific and industrial chemistry.

Fundamentally, the various practical ways of improving the inheritance of a race or breed include sleection, which means that some parents are deliberately caused to have many offspring, others few or none at all; inbreeding, or mating closely related animals, and its opposite, outbreeding; mating like to like regardless of pedigree; and mating unlike individuals regardless of pedigree. Usually in a breeding program, selection is combined with one or more of the other possibilities.

Three facts must be kept always in mind, and due allowance made for them.

(1) Hereditary factors are sorted out by chance before being passed on to offspring.

Suppose there are seven slips of cardboard, each one painted a different color on each side—one black on one side, white on the other; one gray and brown; one green and red; one yellow and blue; one orange and purple; one pink and lavender; one crimson and scarlet. They are thrown into the air. They come down on a whirling disk, each slip with one side uppermost. As the disk whirls, the colors appear as a single tone. This tone is the character of the animal. If a single slip had happened to fall with the other side up, the animal's character might be entirely different.

This is something like what happens in inheritance.

(2) Environment has an effect. Examined in daylight, the disk looks different than it does under the yellow light of an electric bulb, though the slips are exactly the same.

(3) The observer may make mistakes. If he has to match or grade several disks, for example, in accordance with the amount of a certain color, he would not do a good job if he were color-blind for that color.

In general, it may be said that the details of a breeding program may be complicated, but the main outlines are clear and simple. When these main steps have been taken, there is not much freedom of choice left among the details. Thus a breeder will rarely need to solve a complicated problem in order to make an important decision.

PRODUCTION TESTS

The first thing is to have an ideal in mind toward which to work, though this does not mean that the ideal has to be a fixed one; it may have to be flexible to meet changing economic conditions. The definition of each character should be as exact as possible. A decision should be made as to the importance of each deviation from a desired character. Deviations should be measured as accurately as possible.

The desirability of keeping out nonessentials and sticking to essentials has already been stressed. To cull a productive cow because she is not quite the right color, for example, makes it that much more

difficult to breed productive cows. The ideal should be as simple and practical as possible.[6]

Historically, tests for practical productiveness have always been important and have not been stressed nearly enough. Elsewhere in these articles on livestock breeding, the necessity for developing yardsticks for the measurement of valuable characters, particularly in the meat animals, is discussed. Tradition has it that Bakewell made many measurements and notes on the cuts of beef and mutton from his animals and even preserved some of the choicer cuts pickled in jars as a sort of museum to record his progress in improving his breeds for the butcher.

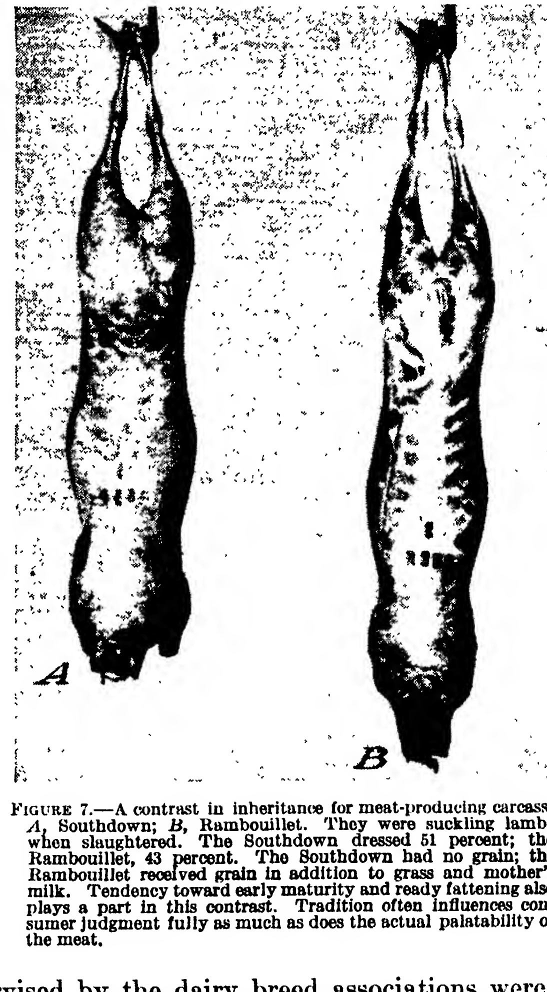


FIGURE 7.—A contrast in inheritance for meat-producing carcass: *A*, Southdown; *B*, Rambouillet. They were suckling lambs when slaughtered. The Southdown dressed 51 percent; the Rambouillet, 43 percent. The Southdown had no grain; the Rambouillet received grain in addition to grass and mother's milk. Tendency toward early maturity and ready fattening also plays a part in this contrast. Tradition often influences consumer judgment fully as much as does the actual palatability of the meat.

A surprising number of the early British breeders of cattle and sheep had had some years of experience as butchers before they became breeders. Thomas Bates a century ago paid attention to the feed records, milk records, and occasional churn tests of his Shorthorn cows. In North America, shearing contests attracted wide attention and were important in the development of the Vermont Merino. Speed at the trot or pace was the main element in the standard around which the American Standardbred horse was developed.

Production tests supervised by the dairy breed associations were an American innovation, largely the work of Solomon Hoxie and his friends. They had a doubtful struggle until near the turn of the century, when their success was assured by laboratory discoveries which produced reasonably simple and usefully accurate tests for the fat percentage of milk.

[6] The importance of simplification may be shown numerically. Other things being equal, progress in selecting for one trait, when selection is based on that trait alone, will be the square root of n times as fast as when selection is for a number of traits equal to n. Suppose we are selecting for four traits. Then $n=4$. The square root of 4 is 2. Thus progress in selecting for one trait alone would be twice as fast as in selecting for it equally along with three others; it would be three times as fast as in selecting for nine traits, since the square root of 9 is 3. If the traits are positively correlated with each other, progress will not be slowed quite so much, but such correlations make only a little difference unless they are high; moreover, correlation may be negative and make progress a little slower than the simple formula indicates.

Some of the swine-breed organizations have always required that the breeder state the number of pigs farrowed and the number raised, but there has been no requirement that disinterested witnesses attest the record. Experiments with the Danish plan for testing the feeding ability and killing quality of swine were begun by the United States Department of Agriculture and the agricultural experiment stations of Iowa, Minnesota, Wisconsin, and West Virginia in or soon after 1926. At least one swine-breed association—the Hampshire—has started an advanced registry with admission based on performance of offspring in official feeding or slaughter tests, or on winnings of offspring at recognized shows, or on inspection and farm performance. Late in the 1920's some attempts were made in Michigan, Utah, and California to organize an advanced registry for Rambouillet sheep based on yield and quality of clean wool. Pulling tests for draft horses using a dynamometer developed at the Iowa Station were begun early in the 1920's and are an attraction at many livestock fairs today, although they have not yet developed into a test commonly applied to brood mares or stallions. The Hereford breed has established a Register of Merit based on the show winnings of offspring. The articles on the different classes of livestock give additional information on these production tests.

LOCAL IDEALS AND INTERMEDIATES BETWEEN EXTREMES

Some traits are consistently desirable or undesirable in all localities and under all circumstances—resistance or susceptibility to disease; efficiency or inefficiency in the use of feed; high or low fertility. Other things are desirable under some circumstances but undesirable under others.

Generally speaking, extremely large size and weight are more likely to be desirable in regions where pasture and feed are always good than in regions where there are frequent periods of scarcity, as in much of the range country, or in the common management of cattle in the Cotton Belt.

It is also important that each breeder consider his own feed resources and market outlets and make his ideal correspond closely with what will usually be most profitable in his locality and for his type of farming. If this were carried very far, it might lead to a different ideal in every type-of-farming area, although the breeder would be restrained by the general market demand from going as far as local conditions might otherwise dictate. Livestock breeders have probably not gone as far in this direction as they could with profit.

The ideal is often an intermediate rather than either extreme, or demands a certain balance among characteristics rather than that each one should have a certain degree of expression. Livestock breeding in North America is full of examples of this. In Poland China swine there are at least two extreme types—chuffy, fat animals and long, rangy animals. In cattle there are the extreme beef-type and the extreme dairy-type breeds, and in sheep those especially noted for wool and those especially notable for mutton. In poultry there are the early maturing, high-producing egg breeds like the Leghorn, and the slow-maturing, meaty breeds like the Brahma. In horses there are the heavy draft animals and the light, fast race horses or trotters. Each extreme has a specific field of usefulness, but in each case the most widely useful type is likely to be an intermediate between extremes.

Breeding evidence indicates that the intermediate type is not always easy to maintain or improve. There is a tendency for it to split and go toward the extremes. It may never be possible, in other words, to get an intermediate as perfect in its way as the extreme type. The problem, however, is a challenge to breeders, and plant breeding indicates that it is not impossible to solve. Plant breeders regularly combine several economically important characters, such as high yield, high quality, and high disease resistance, in a single variety. Though even in plants this has not been easy, large numbers and skillful technique being necessary to get positive results, nevertheless these results indicate that, where there are no physiological hindrances, it should be possible in the case of animals to hold the gains made in the development of intermediate types and perhaps to bring about improvements as yet hardly dreamed of, developing intermediate breeds superior, for example, to the present Rhode Island Red in poultry, the Milking Shorthorn in cattle, the Morgan horse, the Hampshire hog.

In this connection, it should be noted that in the United States, reliance has been placed mainly on importing breeds already regarded as highly improved in their native lands. Partly this was a natural desire to save time by starting where other breeders left off rather than starting at the beginning and ignoring the improvements already made; but in many cases it is likely that something was lost by ignoring the adaptability to American conditions already attained by the local stock. In retrospect, it looks as if American farm animals might now have been even better suited to the needs of American agriculture if more of the breeds had been built on a foundation of native stock blended with the excellence of the imported breeds—as the American Saddle horse was built on a native foundation but with extensive use of Thoroughbred stallions—rather than going over completely to pure-breeding the imported race, as was done in most cases.

Importations began almost as soon as there was any recognition of improvement in the native lands of the breeds. Merino sheep and jack stock from Spain came before 1800, and Shorthorns and Herefords at about the same time. From then until the Civil War small importations came from widely scattered sources—as cattle from Great Britain, the Netherlands, and India; Angora goats from Turkey; sheep from France and Great Britain; swine from China, Italy, and Great Britain; and horses from many lands. Even camels were imported between the Mexican and Civil Wars in one extensive attempt to adapt them to the needs of army transport in the Southwestern States. The high tide of importation came in the era of agricultural expansion which began at the close of the Civil War. Many of the major breed associations were organized in the late seventies and in the eighties of the last century. The agricultural depression of the nineties checked much of the importation.

As a protection to the health of livestock in the United States, importations of breeding stock from certain countries in which dangerous diseases exist are restricted by Federal quarantine regulations. Such restrictions have had the effect of preventing importations of certain classes and breeds of livestock common to such countries.

Recently the Department has brought into this country breeding stock of Danish Landrace swine, Hungarian Puli dogs, Hungarian

Nonius horses, and Red Danish cattle—animals that have reputations for superiority in Europe and that may be useful in breeding experiments.

LOCATING THE BEST ANIMALS

It is not an easy matter to estimate whether an animal has the hereditary factors that will enable it to approach the desired ideal in a given environment. A mere record of purity of breeding is not enough. Pedigree, individual performance, and progeny tests must all be taken into account. Each has value if it is of the right type, but each also has limitations. All three of these methods should be used in practical breeding, but no single formula for the amount of attention to give to each can be generally valid. Sometimes it may be necessary to cross two or more breeds in order to get into a herd all the kinds of genes it is desired to combine in the ideal. In practical breeding this is usually done as a last resort if there is no way to find all the desired inheritance within one breed, and only when the breeder and his associates are prepared to maintain a flock or herd large enough to have at least three to five sires in use at all times.

Pedigree comes first in time and is cheapest. But even though certain factors are known to be present in the parents, it is impossible to tell just what combinations will turn up in a given individual among the offspring, as we have seen in the analogy of the colored cards; but it is possible to tell what combinations will turn up on the average in a large number of offspring considered as a group.

More Data Needed in Pedigrees

Too often, as already noted, pedigrees are not of the right type and thus have little or no practical value. The most valuable pedigree is one that gives the full performance record—bad points as well as good points. A desirable breeding animal is one that is directly descended from proved individuals on both sides of the pedigree. To rely on remote ancestors or relatives is to increase the element of guesswork.

The extreme limit that can be approached by the study of pedigree would be reached if one knew the exact heredity of both sire and dam. Yet even with that extreme knowledge, the chance or sampling nature of Mendelian inheritance would insure that some offspring would be above and some below the average of the parents in each respect in which the parents were not both genetically pure. Except for genes so abundant that most members of a class or a breed are already genetically pure for them, one or the other or both parents will in more than half of the cases be genetically impure for any particular pair of genes. This gives plenty of room for one offspring to vary far from the average of its parents, but such variations, being random, tend to cancel each other in the averages of large numbers of offspring.

The Performance of the Individual

Individual performance is second in time and cheapness to pedigree analysis, and is usually most accurate in a population not previously selected on either basis. It cannot be used for one of the sexes in sex-limited traits like litter size, egg production, milk production,

or some temperamental traits such as the working disposition of a gelding; and it cannot be used for either parent in the case of traits that can be measured only when the animal is dead. such as yield and quality of meat.

Besides being a basis for direct selection, individual performance is, of course, used in pedigree selection and progeny tests. Pedigrees are weighted averages of the individuality and performance of ancestors and collateral relatives, while progeny tests are averages of the individuality and performance of offspring.

Individual performance, however, is not an accurate indication of the ability of an animal uniformly to pass on desirable traits to its progeny. Other things that interfere with using this as a guide to breeding value are:

(1) Mistaking the effects of environment for the effects of heredity.

(2) Incompleteness and errors in the methods of measuring merit.

(3) Dominance, which sometimes makes an animal that has inherited something from only one parent just as meritorious an individual as another that has inherited it from both parents.

(4) Complex gene interactions, which may be confusing in all sorts of ways. For example, if an animal has four genes of a combination of five which together would produce a desirable result but separately produce no effects or undesirable ones, such an animal's own performance or appearance would cause it to be rated as no better or worse than one that had none of the five genes; yet it might be valuable as a breeder to transmit the desirable genes. Not much is known definitely from actual experiment or observation about the general importance of complex gene interactions as a source of error in domestic animals; but from the nature of the case it is to be expected that they would quite often be unimportant in a population which is first being turned by selection in a new direction, but might often be quite important in a population which has been under intense selection toward a certain goal for several generations.

The first and second of these sources of error—environment and mistaken judgment—are almost certain to be the more serious ones in the case of economic traits, since these are generally much influenced by environment and, because of their physiological complexity, by many genes. Dominance is not a very important source of error except for rare recessive genes—such as lethals, that is, factors so deadly that their presence in the homozygous condition does not permit the animal to survive—which individually have a large effect. The above statement does not hold true, however, for a group of animals that has already undergone considerable preliminary culling. In this case, dominance may be responsible for a rather large portion of the remaining discrepancies between breeding value and individual appearance or performance.

Theoretically the breeder may reduce the error arising from environmental effects and imperfect measurements of merit by (1) analyzing the factors in the environment and correcting the record to bring it in line with what it would have been under standardized conditions—though it may be impractical to correct for more than a few of the most important factors; and (2) using lifetime averages

instead of single records or ratings.[7] Prominent among traits for which this last might be helpful are annual milk and butterfat production by dairy cattle, wool production by sheep, strength or speed of horses, fertility of swine, and the more plastic details of type or conformation or action. Under practical conditions, however, there are so many factors that interfere with getting significant lifetime averages that they are not greatly used. They would be even less useful for egg production of poultry in cases where only a minority of the females are kept for more than 1 year. For certain other traits that can be measured only once, a lifetime average has no meaning. Examples would be early maturity, growth rates, longevity, dressing percentage or other characteristics observable only at slaughter time, and—under practical conditions—efficiency of the use of feed for growth or fattening.

Errors in selection arising from dominance or from complex gene interaction can be corrected only by study of the pedigree or resort to progeny tests—which means getting away from the individual animal and trying to see its genetic possibilities through its ancestors and descendants. Usually such errors can be only partly corrected in this way. In some cases—for example, red color in black breeds of cattle—where pure recessive tester stocks are available and can be used economically, the progeny test can effectively overcome the errors introduced by dominance. Such a test is necessary to determine which progeny of a sire or dam are carrying red if a red calf has been dropped, since to produce a red calf both parents must carry the recessive character.

The Progeny Test

The third basis for selection, the progeny test, discussed at some length in the other livestock articles, goes back perhaps 2,000 years. Varro had recommended that the excellence of rams and boars be judged by the excellence of their get, and there is no reason to think the idea was original with him.

The progeny test, however, often comes so late that it finds its chief usefulness as a part of pedigree records. In the case of the larger animals, too, sometimes only a few of the offspring can be tested, whereas to be fully useful, the progeny test should be extensive enough to overcome the statistical errors of Mendelian sampling in the transmission of factors from the parent to the offspring. Sire indexes, discussed in the article on dairy cattle, are helpful in overcoming other difficulties such as differences in the merit of the mothers of the progeny.

[7] In the general case the portion of an animal's apparent difference from its herd average, which is most probably the real difference where the animal's own record is an average of n unselected single records, is $\frac{nr}{1-r+nr}$ of its apparent difference, where n is the number of unselected records and r is the average degree of resemblance (coefficient of correlation) between different unselected records of the same animal within that herd. Where r is nearly perfect—that is, where an animal's different records are nearly always alike, as in the case of coat color or many skeletal differences—there is little need to use lifetime averages. But much is gained in traits where one record of an animal differs widely from the next without apparent cause. For example, in annual butterfat records of dairy cattle, the correlation between records of the same cow in different years in the same herd seems usually to be somewhere around 0.33 to 0.50. With the smaller figure—that is, where environmental forces are less well controlled or corrected—one would make the least mistake by valuing the animal at 0.33, 0.50, 0.60, or 0.66 of its apparent superiority over the herd average, according to whether its record were the average of 1, 2, 3, or 4 years of records. Where environmental forces are sufficiently well controlled or corrected so that the correlation is 0.50, the corresponding figure would be 0.50, 0.66, 0.75, and 0.80. The use of lifetime averages costs very little if records of production or type at certain intervals are already available.

AN ANALYSIS OF TWO METHODS OF MATING

Inbreeding, outbreeding, and cross-breeding have been discussed earlier in this article, at least in their bearing on a possible program for further progress. For a more detailed discussion, centering on practical operations, the reader should consult Federal or State bulletins, or a good textbook. Mating like to like and mating unlikes have not been touched on, however, and something about the effects of these two methods will be given here.

Mating like to like was perhaps the first method used by animal breeders, since it is the most obvious. It apparently increases the likeness between parent and offspring, or among sibs, and therefore seems to give the breeder increased control over heredity. This, however, is deceptive. Actually, mating like to like increases the variability within the breed, and much of the resemblance between the parent and offspring is merely by contrast with this greater variability. There is very little effect on homozygosis or genuine fixation of type.[8] Nor is there much effect on traits that are considerably influenced by environment, since the effects of environment would in themselves seem to make animals alike when they really were not, and therefore would tend to prevent the mates from being very much like each other in their heredity, even though they might have been chosen to be very much like each other individually. By contrast, inbreeding has a large effect on such traits, because animals are mated to each other purely on the basis of their being closely related by inheritance, and inherited traits that tend to make them react in the same way to a given environment become concentrated.

Most of the effects of mating like to like are realized in the first or second generation. If it is continued after that, it merely holds the condition of increased variability. All in all, the practical usefulness of the tool, as genetics is understood today, is largely confined to increasing variability, and to bringing about a rapid change to extreme types. It may be useful to a breeder whose ideal is different from that of most of his fellow breeders.

When there is agreement on the ideal for a breed, such mating of like to like as can be practiced increases the variability of the breed, and therefore should make selection more effective. Something of that kind happens where breeders are agreed on the ideal but some, because of superior skill or more money, can purchase more nearly ideal groups of males and females than others can. This leads to a greater diversity in the breed than if every herd were truly a random sample of the males and females of the breed. From the principles involved, it seems doubtful that the process can go very far in breeds in which there is substantial agreement about ideals, but actual data to verify this are practically nonexistent. Even in cases where there is a diversity of ideals and a breed is split in two directions, as in the case of Poland China swine 20 to 30 years ago, when extreme "hot bloods" and extreme "big types" each had ardent advocates, and the American type and the island type in Jersey cattle, the separation brought about by mating like to like is rarely anywhere near complete unless there is also considerable separation by pedigrees.

Mating like to like, regardless of pedigree, is easily confused with selection. Many of the statements about it in print do include

[8] Mating like to like so perfectly that the correlation between genotypes of mates was one-half would decrease heterozygosity only about one-eleventh of what it would have been under random mating, if 5 pairs of genes were involved, and only about one twenty-first if there were 10 pairs.

something about the effects of selection. The difference may be shown by an illustration. If a cattleman has bought two bulls to be used equally on his herd of cows, he can practice no further selection so far as those bulls are concerned until their calves come. His power to select them was exercised when he chose them rather than other available bulls, and when he decided that these two were to be used equally on his herd. He can, however, still practice the mating of like to like by dividing up his cows so that each shall be mated to the bull more like her, or he can practice the mating of unlikes by mating each cow to the bull less like her.

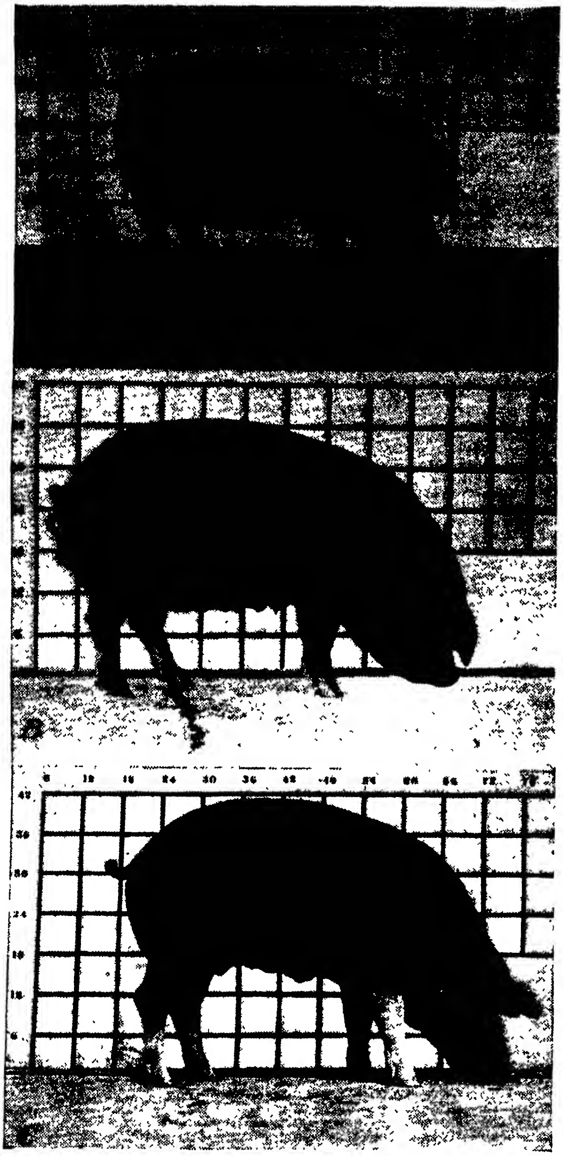


FIGURE 8.—Representatives of three types of Poland China sows showing the wide variation breeders have obtained within the breed: *A*, Small-type sow; *B*, intermediate-type sow; *C*, large-type sow.

Mating unlikes is frequently practiced where the ideal of the breeder is an intermediate. An animal too extreme in one direction is mated to another which is too extreme in the opposite direction. In the process of selection also, the breeder uses this method because he cannot find perfect animals. If his females are unusually good in some respects but below average in others, he will usually be careful to select for his next sire an animal especially strong where the females are weak, but since he cannot get a sire perfect in all points, he compromises by accepting one a little weak where most of his females are strong.

Mating unlikes is the most powerful tool for immediately producing uniformity in a breed, but it exerts nearly its full effect in the first generation. Inbreeding, if carried to the limit and accompanied by selection which would discard all but one inbred line, would produce

much greater uniformity, but it would require more time, and because of its other consequences it is not often used for this purpose in practical operations.

Contrary to widespread opinion, the mating of unlikes has almost no effect on homozygosis.[9] Unless one starts with a group of inbred lines, he need not fear any material loss in genuine fixity of inheritance when he practices this method of mating. For the practical breeder the mating of unlikes is a very useful means of keeping the breed in the middle of the road and discouraging extremes. This is especially advantageous where the ideal is some kind of an intermediate. The breed tends to return almost at once to its original condition when the mating of unlikes is discontinued.

Future Progress in Livestock Breeding Demands the Cooperation of Four Partners

LIVESTOCK improvement is a matter that concerns a vast number of people. At one end is the consuming public and such groups as the meat packers; at the other end, scientific workers, professional breeders, and farmer-producers. Each group has its own interests and attitudes, but all of the groups—public, scientists, breeders, and producers—have a stake in the future of livestock breeding, and cooperation is necessary if there is to be progress.

THE FUNCTION OF THE SCIENTIST

The situation of the scientific experimenter has already been discussed. He finds himself faced by problems that in some cases are so complex as to be seemingly insoluble. The influences of heredity, food, and environment in the development of an animal are often extremely difficult to isolate. Most of the characters with which the animal geneticist deals show a wide range in expression, and they are affected by an undetermined number of genes, probably large. Practically nothing has been done toward identifying specific economic characters with definite genes, and there is even good reason to doubt that much can be done in this direction for traits of genuine economic importance, without using larger numbers of animals and more money than would ever be available for the work, not to mention unlimited time. Cattle cannot be handled experimentally by the millions like pomace flies; and even in the case of pomace flies, though they are extraordinarily favorable material, the genes that have so far been definitely mapped correspond for the most part to such characters in animals as coat color or the presence or absence of horns.

Moreover, there is always the fundamental difficulty inherent in the chance sampling between pairs of genes that is nature's method of passing on inheritance. Of course it will never be possible to pick desirable genes for an animal as items can be picked from a catalog to make up a combination order. Still, by a system of inbreeding, by carrying on the work for several generations, and by wise selection, it

[9] For instance, in the impossibly extreme case of mating exact opposites, without selection, for a trait affected by five pairs of genes, the heterozygosis is increased by only about one-nineteenth of what it would have been under random mating.

should not be impossible to develop strains of livestock that carry many desirable genes and are valuable breeding animals.

In other words, to offset the case against the possibility of progress, which is not difficult to make, there is the record of achievements already made; the great advance in our knowledge of how heredity operates, which makes it possible to formulate experimental procedures and breeding practices based on something better than guesswork; and the real and steady advance in plant breeding—a science that also, at one time, had to start from scratch. The amount of experimental work in genetics with animals is extremely limited, even in the case of such small animals as the rat and the guinea pig, compared with experimental work in nutrition, for example, or in plant genetics. As long as there is still so much undone and untried, and so many problems are pressing for attention, the situation cannot be considered hopeless.

The scientist alone is equipped to explore this field of experiment and research. His part may not be dramatic and his progress may be slow, but he should be able to progress provided he adheres to certain principles. He may have to concentrate on character analysis as a prelude to further character synthesis. He must refuse to be too much influenced by the immediate pressure of economic considerations. It may be quite as useful, for instance, to isolate a strain of low-producing dairy cows, with a view to discovering what is responsible for low production, as to concentrate eternally on trying to get high producers. The scientist may have to forget some preconceived notions of the roles played by genetics, endocrinology, and anatomy. He must avoid having his judgment warped by traditional breed standards. He should be free to work on a sufficiently large scale and over a long period.

THE INTEREST OF THE PROFESSIONAL BREEDER

The point of view of the breeder of animals used largely as breeding stock rather than for the market is that his operations must yield a profit, and the breed standards must be maintained. Professional breeders have been concerned for generations with the incorporation of desirable qualities into their stock and they have believed that these qualities could be maintained and improved through pure-breeding practices. They make almost constant use of selection, although in many cases the effectiveness of the selection is relatively slight. Ever since livestock exhibitions began, the professional breeder has followed show-ring standards rather closely, and the breeder who could win consistently at the shows soon became the leading breeder of registered stock in his community. Through the application of this system, the meat breeds of livestock have changed, but to what extent the homozygosity of the breeds has changed is open to question.[10] Show-ring standards are arbitrary at best and they are superficial genetically.

In many cases the power of selection for meat characters amounts to practically nothing when based on present standards of measurement. The breeder makes frequent mistakes and by a single unfortunate selection of a sire he may easily lose all he has gained. He is

[10] Several breed studies have shown that current pure-breeding practice tends to fix something like 0.33 to 0.50 percent of the unfixed inheritance per generation, plus or minus whatever amount—probably small—is changed by selection, and minus whatever is lost through accidental or fraudulent registration of grades. There are thus no very valid theoretical reasons for expecting a recognized breed to be very much more homozygous today than it was when it left the hands of its founders, in whose small herds the limited size of the population and the deliberate line-breeding to a few choice animals were forces powerful enough to increase homozygosity noticeably.

greatly in need of new measures of excellence that will enable him to make further progress in unifying his stock for those characteristics for which they are valuable.

If we ever reach the stage where it will be possible to judge meat animals in the show ring on the basis of ability to transmit economy of gain, superiority of meat quality, and high fertility, then the breeder will be in a position to know with certainty where the strains of superior breeding worth are located. This will be true particularly if there comes a time when data of this kind can be recorded for large numbers of animals within each of the meat breeds.

The professional breeder has a heavy stake in the existing situation, and he cannot be expected to make radical changes that would

FIGURE 9.—Grade Aberdeen-Angus calves bred and fed by a prize winner in a Missouri carload baby-beef contest. These calves were born in early spring, fed throughout the summer while nursing their dams, and sold for choice Christmas beef. The 20 calves averaged 740 pounds at 9½ months. Early maturing types are demanded for such early marketings.

jeopardize his gains. Yet he must keep an open mind and be ready to meet changing conditions. It is true that he is influenced by the producer's needs, but he in turn influences the producer by setting up ideals, so that he has a great responsibility in the animal industry. While cost and other factors would probably prevent the breeder from initiating large-scale experiments involving any great departure from existing methods, he should be the first to recognize the need for these experiments, to cooperate in them fully, and to put them to practical use as soon as they show good results.

THE INTEREST OF THE FARMER PRODUCER

As for the farmer—he is relatively free to change his system of breeding, the blood lines used, and his general procedure whenever he believes this is necessary to increase the profitableness of his stock. The limitations set by the current show-ring standards for pure breeds seldom carry much weight with him. His interest lies primarily in the cost of feed per hundred pounds of gain, uniformity of growth, and a product that will sell well. Because of the constant changes in market demand, he is frequently called upon to bring about rather drastic changes in the characteristics of his animals. It is important, therefore, that he maintain stock which is sufficiently flexible so that he may be able to make these changes without too much difficulty. At the same time, it is important for him to possess

breeding stock that will uniformly pass on economically important characters to the offspring.

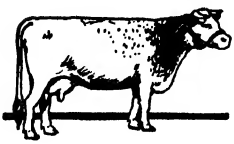
The farmer is greatly interested in the development of strains that are more economical to raise and that will produce a high-quality product commanding a premium on the market. On the other hand, the scientist, the professional breeder, and others interested in livestock improvement have not given enough attention analytically to these practical considerations. At the same time, if the price of improved strains is too high, the farmer may not be able to sell the offspring on the market at a sufficient premium to justify the use of the improved stock. This is one reason why so many grade sires are in use. As long as there are grade animals equal in performance to many of the registered ones, it is certain that the farmer will continue to use them in preference to registered animals. In future developments, it must be kept in mind that the farmer is interested primarily in profits and only secondarily in some of the things that the show-ring and breed associations have fostered.

Farmers who are interested in meat or wool production for profit do not have a fixed ideal, because ideals change with changing economic conditions. The breeder who is dealing with a class of livestock possessing sufficient flexibility so that its course may be varied in step with changing economic conditions is in a particularly favorable position to maintain satisfactory, long-time average profits. A good example of the need for such flexibility is furnished by the lard breeds of swine which were developed to be a help in marketing a varying and unpredictable corn crop, turning large surpluses into heavy hogs with high yields of lard, while small corn crops went to market as lighter and leaner hogs. In recent years a shrinking export market and low lard prices have made it likely that the ideal for swine breeders will tend toward a hog with more lean and just enough lard to make it sell well. But this situation in turn may change.

It takes at least one animal generation to effect any change and may well require two or three generations to make significant progress on the road toward a new ideal. In the meantime, the ideal may have changed again, owing to changing economic conditions. Thus the ideal itself is largely dependent upon economic factors that can change more rapidly than a breed average can be changed by the breeders. At the present time a certain amount of flexibility and variation is a part of the ideal for those characters largely affected by economic conditions. From the standpoint of the experimenter or the scientific worker in animal husbandry, this situation is a challenge to know more of the inherent make-up of the various breeds of animals, so that when a change in economic conditions does occur, breeders can more surely and more quickly effect the necessary modifications in their stock.

Not all characters, of course, are affected by economic changes. High reproductive power and disease resistance are desirable under any circumstances, especially in view of the competition in animal husbandry today. Examples of low fertility or even of sterility in farm animals having excellent conformation are not rare. This may often be the result of faulty husbandry rather than of faulty heredity, yet there is always the suspicion that possibly selection from the production standpoint may have affected the endocrine balance to the detriment of reproductive power. There must be an ideal for reproduction as well as for production, and the two must be so balanced that the producer can maintain the ratio of numbers to quality that will yield the maximum return.

Beef and Dual-Purpose Cattle Breeding



By W. H. Black, in Charge of Beef and Dual-Purpose Cattle Investigations, Animal Husbandry Division, Bureau of Animal Industry

IT IS widely conceded by scientists that recent progress in the breeding and genetics of meat animals is not comparable with that in the case of plants. There is a critical attitude in the air, and a desire to make a reexamination of fundamentals to discover, if possible, whether accepted methods are at fault and whether worth-while improvements can be made. This is the viewpoint reflected by the present article on beef and dual-purpose cattle. It is realized that such a discussion is likely to bring the charge that cherished practices are being unjustifiably criticised. The risk must be run. An omelet cannot be made without breaking eggs, if only to find out whether they are suitable for the omelet.

In this article, no effort has been made to summarize the voluminous literature on the history of cattle breeding. The author has confined himself to those aspects of the subject that seem most pertinent to the purpose of the discussion.

Fundamental Problems in the Improvement of Beef Cattle

IN CONNECTION with the survey of improvement in beef cattle, questionnaires seeking information on birth weights, gains, efficiency of feed utilization, and quality of the animal and carcass were sent to the agricultural experiment stations in each of the 48 States. An invitation was extended in the questionnaire to include any other recorded data on the experiment station beef herds that might be of value in locating superior breeding animals. In addition, each station was requested to submit a list of breeders within the State who were considered to have superior breeding cattle in their herds.

These forms were filled out in part by 18 stations. Though quite a number have herds, only five mentioned any definite breeding

projects with beef cattle, and some of these included merely the maintenance of a herd for instructing college classes in animal husbandry, with no intention of collecting data on breeding problems. Several of the institutions reported keeping three herds of beef cattle—Aberdeen-Angus, Hereford, and Shorthorn—so that representatives of each would be available for use in connection with class work in judging, and for general demonstration. In many cases, for reasons of economy, only one or two breeds are represented.

The prevailing breeding systems used in college and station herds include more intentional line breeding than is the case with classes of livestock other than beef cattle. The data regularly recorded include pedigrees, birth weights, and sometimes weaning weights. In a very few cases a regular type rating of each animal is made at weaning or at some definite later date, but there is little uniformity in such systems among different institutions.

It should not be inferred, however, that little attention is given to the individual animals, because quite the reverse is true. Probably no other animals except horses are studied so carefully and remembered so well by those in charge as cattle. But it is open to question how adequate such study is for determining real merit; and in addition, the knowledge is carried in the memory of men and usually is not permanently recorded in the form of systematic grades, scores, drawings, measurements, and descriptions. The contribution being made to a store of recorded information that might be useful in locating superior breeding stock in the various breeds of beef cattle is therefore an extremely modest one.

WANTED—METHODS OF MEASUREMENT

The survey has not been extended to include the private breeders although experiment stations were asked to submit a list of breeders who had superior breeding stock. Eleven stations submitted a total of 64 names. This list is by no means complete. It includes those who have exhibited cattle at stock shows or advertised most extensively. Show-ring winnings are the most common measure of superiority used in these herds, and the reputation of a herd rests to a large extent on this factor alone. Such information is obviously too all-inclusive for the purpose of differentiating superior germ plasm, and on this basis alone it would be inaccurate to list these 64 breeders as the only ones in the country who have superior breeding animals.

Among livestock men, the opinion is probably widespread that it is easy to locate the superior breeding stock in this country. The present survey shows that in reality this is far from an easy matter. The fact is that before herds can be surveyed to locate superior germ plasm there must be a method of measuring beef characters that, over a period of time, will yield data from which at least an approximation of proper ranking for superiority of germ plasm can be made. At the present time the breeder is using the most readily available indication of what he thinks is superiority, namely, show-ring winnings. Until the limitations of this method are clearly defined and a more exact method which the breeder can afford to use is developed, there is little on which to base an effective survey of beef-cattle germ plasm.

The next step, therefore, is up to the experimenter.

The reason usually offered for the great scarcity of breeding research in connection with beef cattle is the high cost of herd maintenance over the long period of time required to obtain the necessary data. But perhaps this is not the chief obstacle after all. When scientists undertake basic research aimed at the solution of the herd-improvement problems that confront progressive breeders, the first difficulty they will encounter is the lack of adequate methods for evaluating and recording merit in beef animals. Developing methods for doing that is the most important problem facing both the geneticist and the cattle breeder today.

SPECIAL PROBLEMS IN BREEDING BEEF CATTLE

As soon as sufficient progress has been made in the development of methods to measure variation in beef cattle, the geneticist will be in a position to investigate the fundamental breeding problems, which concern the inheritance of the characteristics responsible for breeding and feeding efficiency in the production of high quality products (fig. 1).

These are not new problems that have suddenly risen out of the complexities of modern civilization. They existed when the early breeders a century ago were attempting to improve the ancestors of the common beef herds of today. Undoubtedly these men recognized the necessity of giving attention to the characters that were of most importance to the butcher and the consumer, and directed their efforts toward selecting for such characters. Some also recognized that economy of production was an important characteristic in cattle and made efforts to improve their herds in this direction, although their measure was probably an indirect one based on observation of the animals that fattened most readily. The system of close breeding followed by many of these early breeders quickly fixed certain points of superiority on which the reputations of the outstanding breeders were made. As time went on, however, attention was paid, expecially during periods of rapid expansion, to characteristics of color and form that had little to do with genuine superiority, but that were useful chiefly in distinguishing and identifying the breeds.

This general system has been followed to some extent down to the present day, when we find breeders giving major attention to type. The assumption has been that this includes nearly all the characteristics that contribute to the value of the animal. Of course during the intervening years the prevailing type has changed, this change always lagging behind a change in market demand. When consumer demand had reached the point where people were willing to pay a premium for animals of a certain size or for certain cuts of a certain quality, breeders began to shift their attention to meeting these demands. This process is going on today and it may be expected to continue.

However, without waiting until human tastes in beef become stabilized for all time—if such a thing could ever happen—we can undertake an analysis of major problems with the assurance that as progress is made, the synthesis of the beef-cattle ideal necessary to meet current demands will be that much easier. Paradoxically, the breeder now tries to synthesize the product before the analysis has been made, that is, before he really knows the inherent make-up of the ideal he seeks. Of course progress is not likely to be rapid in any

FIGURE 1.—Although these two purebred Shorthorn steers are full brothers, they performed very differently on test. Alike in weight at birth, steer no. 66 (*A*) reached the slaughter weight of 900 pounds 91 days before steer no. 85 (*B*). Furthermore, his carcass scored one-half a grade higher and produced 25 percent more dressed beef for each 100 pounds of total digestible nutrients consumed.

event, for several reasons, but there is a great need for more knowledge of the role of inheritance in the development of beef characters if improvement during the present century is to go very far beyond the point already reached as a result of the breeding carried on during the past hundred years.

The important characters that must receive attention in genetic analysis, in addition to fertility and disease resistance, are: (1) Weight for age, (2) proportion of body parts, (3) quality of carcass, and (4) efficiency of feed utilization.

These are all developmental characters affected by heredity, nutrition, and environmental factors acting simultaneously. The three influences cannot be entirely separated for the purpose of study, but—what amounts to the same thing—any one or any two can be

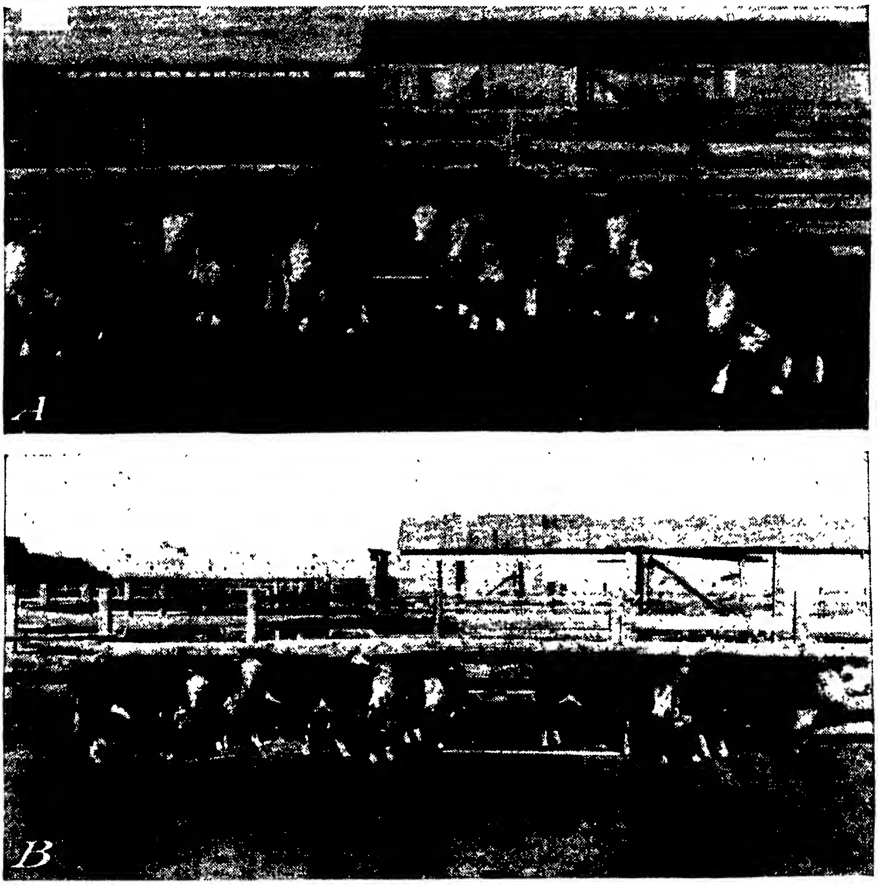


FIGURE 2.—Two groups of Hereford calves in record-of-performance tests at Miles City, Mont. Though sired by different bulls and out of two separate breeding herds of cows, the two lots of calves averaged very much alike in gains, feed consumption, and feed costs. Lot 1 steers (*A*), however, showed greater uniformity, carried higher condition, and outsold lot 2 (*B*) by 40 cents a hundredweight. At Miles City, in cooperation with the Montana Agricultural Experiment Station, an attempt is being made to develop true-breeding strains of Herefords, especially adapted to western range areas, and possessing high fertility and superior quality.

held reasonably constant while variations induced by the other or others are being investigated (fig. 2).

It is not possible to go even this far in separating the characters themselves for study because characters of this kind are so interrelated that variations in any one are associated with changes in the others, and in crosses all follow the type of inheritance known as blending. They exhibit what is known as continuous variability—that is, not sharp distinctions in kind but variation in degree of expression.

These quantitative characters, which influence the development of the whole animal, are not easy to analyze or to control.

A large number of genes affect the development of each quantitative character, and dominance is usually absent. This condition is in distinct contrast to the situation where only one or two genes exhibiting sharply defined dominance and recessiveness are involved, as in the case of the polled versus the horned character. Another example of this type of character is red color, which is recessive to black in the Aberdeen-Angus breed. Such characters are qualitative in nature, segregate sharply, and are easily handled by application of well-known breeding principles. A list of characters with their probable inheritance is given in the following tabulation:

Compilation of some inherited characters (except color) in cattle [1]

Dominant	Recessive
Beef type in head and forequarters	Dairy type in head and forequarters.
Dairy type in rear quarters	Beef type in rear quarters.
Brahman skeleton and dewlap	Domestic cattle type.
High milk yield	Low milk yield.
Low fat percentage	High fat percentage.
Doppelender (in Ayrshires, Holsteins, etc.). Homozygous dominant—sterile.	Normal.
Polled	Horned.
Normal skin over body	Skinless patches on legs and face (lethal).
Udder—4 quarters	Udder—2 quarters.
"Duck-legged condition"	Normal length of legs.
Umbilical hernia in males	No hernia.
Normal tail	Wry tail.
Ear double	Normal ear.
Ear notched	Normal ear.
Defective small teeth	Normal teeth.
Dexter-Kerry (heterozygous). Homozygous dominant—lethal.	Normal type.
Normal type	Bulldog calves (lethal).
Normal	Hairless (lethal).

[1] For color genes in cattle see appendix, p. 885.

Unfortunately, most of these simple characters are not of much economic importance, and, although their mode of inheritance is well known, these facts are of little use to the breeder in formulating a stock-improvement program to enhance ability to produce beef of high quality uniformly and economically. Perhaps the best example of a character inherited in a simple manner which has a relation to meat production is the Doppelender character, which arose as a mutation in certain continental European breeds. This character causes a doubling of the muscles in the hindquarters and loin and is inherited as a recessive. Animals with the Doppelender trait are in considerable demand in Europe for veal, but apparently the character has never assumed much importance in the United States, although it exists among herds in some of the Central Western States.

PAST RESEARCH IN BEEF CHARACTERS

The genetic study of beef characters has received comparatively little attention. Among the outstanding projects dealing with these characters are the following:

Gowen at the Maine Agricultural Experiment Station crossed Aberdeen-Angus with dairy breeds and carried the experiment to the

FIGURE 3.—Africander bull. This breed was imported recently from South Africa for use in attempts to develop superior strains of beef cattle for the Gulf coast area of the United States. Individuals of this breed possess a more desirable beef conformation than the Brahman and similar resistance to heat, disease, and insects. They are being employed in crosses with Shorthorns, Herefords, and both the red and the black Aberdeen-Angus.

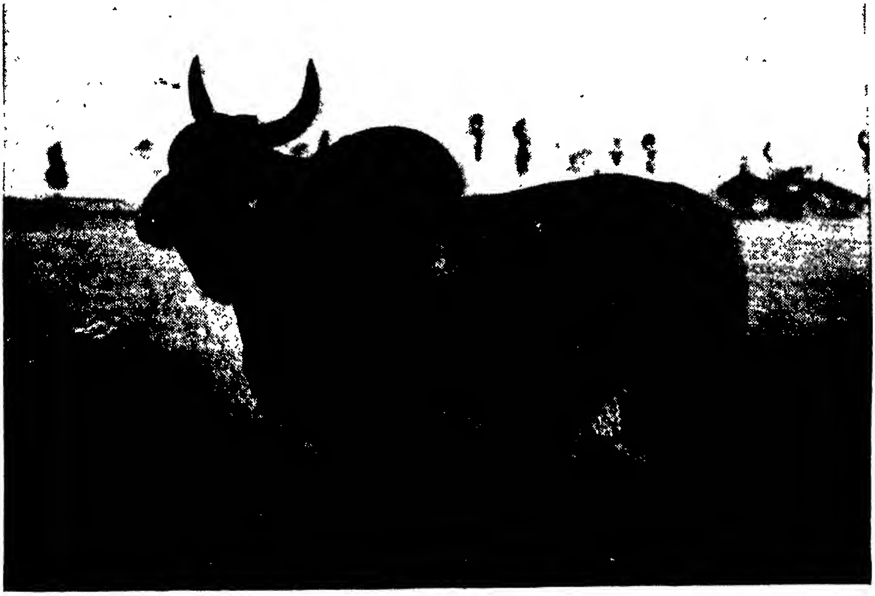


FIGURE 4.—Brahman bull. Although not considered a superior type of beef animal, Brahman cattle have characteristics of great value for tropical and semitropical regions when combined with the beef qualities carried by the Shorthorn, Hereford, and Aberdeen-Angus breeds.

second generation after the cross. Although the dairy and beef qualities seemed to blend to a considerable extent in the offspring, there was some indication of dominance and recessiveness, the dairy type hindquarters and the beef type forequarters tending to be dominant.

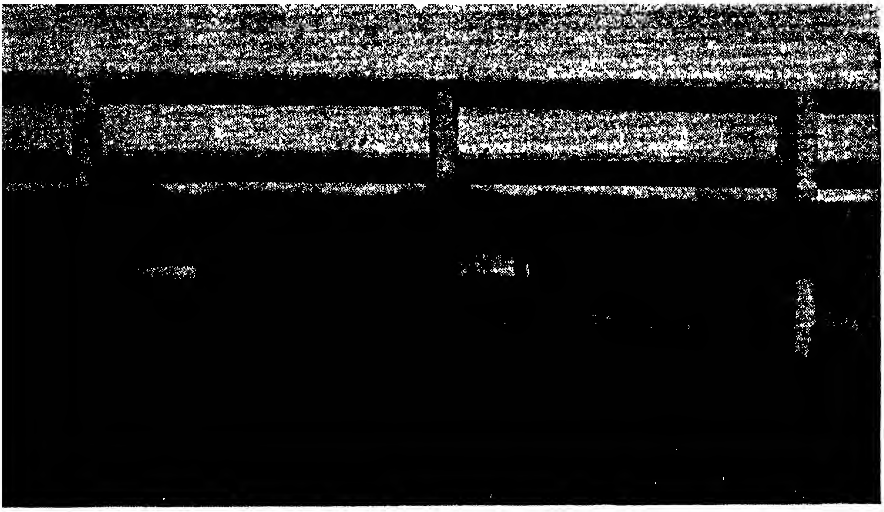


FIGURE 5.—Progeny of first generation Aberdeen-Angus × Brahman heifers bred back to Aberdeen-Angus bulls. The Brahman characteristics have become less pronounced. All of the progeny have been polled and black.

The experiment was not carried far enough and the numbers were not sufficient to yield decisive data on the inheritance of beef characters. As a matter of fact, it was planned for quite a different purpose, namely, to study the inheritance of milk production.

Cole at the Wisconsin Station conducted a somewhat similar experiment in which Aberdeen-Angus cattle were crossed with the Jersey and Holstein-Friesian breeds. The purpose of this experiment was to obtain information on the inheritance of all characters in which the strictly dairy and beef breeds differ. Data taken included color, live weight, various body measurements, size and shape of udder, milk production, and slaughter data, including the weights of retail cuts and chemical determinations of fat. This experiment seems to have been designed to furnish much-needed information, but the analysis of the accumulated records on meat characters apparently has not yet been completed. Attention has been given to the analysis of the milk-production phase of the experiment, however, and reports have been published. It seems probable that the lack of established methods of measuring the meat characters in this long-time experiment will prove to be an obstacle of rather large proportions when the data are interpreted genetically.

In an experiment at the Alaska Agricultural Experiment Station to develop a hardier strain of dairy cattle, crosses were made between the Holstein-Friesian and Galloway breeds. Records were taken on the more important characteristics in which these breeds differ. Although the experiment was not carried far enough to work out the mode of inheritance of milk and beef characteristics, the general appearance of the hybrids was that of a beefy dairy cow with a greater spring of rib and more flesh than the Holstein-Friesian. The hybrids represented a blending of the characteristics of both parents in all points of conformation with the possible exception of width of withers and heavy shoulders and forelegs, in which they resembled the beef type. No detailed data were recorded on the quality of meat produced by these hybrids.

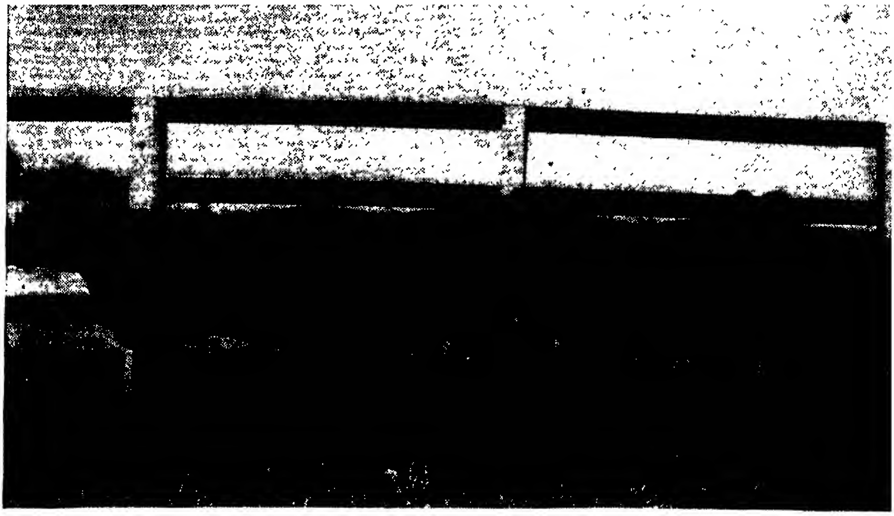


FIGURE 6.—The cross-bred progeny of purebred Brahman bulls bred to purebred Aberdeen-Angus cows. The angularity of the Brahman has largely disappeared, and the animals have shown excellent adaptability to semitropical conditions. Twenty-seven percent of the animals in the first generation are completely polled. The black color is generally dominant in more than 95 percent of the progeny.

The work of Gregory of California on size factors in beef and dairy breeds clearly indicates the complexity of the problems involved in genetic research looking toward beef-cattle improvement. The previous work of various other investigators, including McDowell and Castle, Sumner and Green, and Wright, on the nature of size factors in laboratory animals indicated the existence of general, group, and specific factors influencing skeletal development and weight—that is, (1) factors which affect the development of the whole animal in general, (2) those which as a group affect the expression of several characters, and (3) specific factors affecting only certain characters. The work of Swett, Graves, and Miller indicates that the general factors are the ones that affect linear skeletal development in both the beef and dairy breeds. The work of Haigh, Moulton, and Trowbridge on the composition of the bovine at birth indicates that differences in development of muscle, as measured by diameter, account for a large part, if not all, of the difference in birth weight of calves in beef and dairy breeds.

Gregory's work indicates that some of the genetic agencies affecting muscle diameter in beef cattle are general in character and that they differ from those affecting the linear skeletal development and may be independent of them in their inheritance. He developed an index to express the general conformation of an animal. This index is based on the height of the animal and the round measurement, and represents in a general way the ratio of muscle diameter to linear skeletal development.

It was concluded that conformation is largely the result of the interaction of general, group, and specific growth factors affecting muscle diameter, combined with similar factors affecting linear skeletal development. The index showing the relation between muscle and skeleton was practically constant from birth to maturity for the beef breeds, but in the dairy breeds, especially Jerseys, the index was not constant from birth to maturity. The evidence

indicates that in Jerseys the muscle-skeletal index characteristic of adults is not reached until about 8 months of age. It is apparent that muscle development in beef breeds is somewhat more accelerated during fetal development than in dairy breeds, but the rate of linear skeletal development is about the same in the two groups.

Of course, any measurements of conformation may be affected to a large extent by nutritional factors. However, the work of Gowen on the relative influence of heredity and environment on conformation in Jerseys indicates that, for conformation at least, environmental effects are much less than is generally supposed and in some cases may be negligible. This would indicate that the methods suggested by Gregory in his work may be very useful in identifying variations brought about primarily by genetic differences.

GENETIC *research with smaller animals has clearly demonstrated that families differing greatly in growth rate and weight for age can be developed; and families of mice have been established that differed significantly in efficiency of feed utilization. These characteristics, then, so vital in livestock economy, are affected by heredity and can be changed by the application of genetic principles. Similar results can be accomplished with cattle if the correct procedure is followed. Establishing families whose performance in these respects could be predicted and relied on would be a long step forward. The correct breeding procedure is fairly well established. Lack of data to measure the performance of the animals for selection is the missing link. Research is now being conducted to supply this link.*

NEW TYPES FROM ASIA AND AFRICA

The identification of superior germ plasm in an organism such as the beef animal is frequently confusing because of the powerful influence of nutrition and environment on the development of the characters themselves. In other words, the degree of expression of many characteristics varies with the environment in which the animal lives. Since we cannot separate the animal from the environment in which he develops, we must consider the factors—heredity, nutrition, and environment—together, and try to discover and select the hereditary factors that react with a given set of influences to produce the best animal possible in that environment (fig. 3).

For instance, in the Gulf coast area of the United States the superior animal is the one that can endure the intense heat of summer, resist insect pests and diseases, grow rapidly, and produce a desirable beef

carcass on grass. Because such an animal did not seem to exist in the United States, an attempt was made several years ago on the King Ranch at Kingsville, Tex., to synthesize a strain by crossing Brahman cattle (fig. 4), indigenous to India, on Shorthorn and Hereford cattle. The Shorthorn cross proved to be the more desirable of the two for this purpose, and after about 15 years of constructive breeding there has been developed a meritorious Brahman-Shorthorn cross-bred type of approximately three-eighths Brahman and five-eighths Shorthorn inheritance. This type, which has been named Santa Gertrudis, is red in color and very deep in the body, has good beef conformation, is especially hardy, shows great adaptability to local conditions, and during development has rather extreme weight for age. This new strain traces back to a particular bull that appeared in about the second cross-bred generation and thereafter was used extensively. There was considerable inbreeding in the later development of the strain, which is now reasonably true in type and other characteristics.

AMONG *livestock men, the opinion is probably widespread that it is easy to locate the superior breeding stock in this country. The present survey shows that in reality this is far from an easy matter. The fact is that before superior germ plasm can be located, there must be a method of measuring beef characters that, over a period of time, will yield data from which at least an approximation of proper ranking relative to genetic superiority can be made. This is the most important problem facing both the geneticist and the cattle breeder today.*

A similar experiment has been initiated recently by the Department of Agriculture at its field station located at Jeanerette, La. Here Brahman cattle are being crossed with Aberdeen-Angus for the purpose of producing a solid-colored, polled hybrid with the beefy conformation of the Aberdeen-Angus and the qualities of adaptation to the Gulf coast area possessed by the Brahman. In this investigation another cross, between Africander cattle from the Union of South Africa and a red Aberdeen-Angus strain, is being used to produce a solid-red-colored polled strain possessing the good qualities of both parental breeds.

In the Aberdeen-Angus × Brahman cross (fig. 6), the majority of the first generation hybrids were black in color, but all the bull calves had either short horns or scurs, and approximately three-quarters of the heifers showed signs of horns. The conformation of the first-cross animals has been rather satisfactory, being superior to that of hybrids produced in earlier experiments with Brahman bulls and Hereford and Shorthorn cows. In the back-cross to the Aberdeen-

Angus (fig. 5), all the animals obtained to date have been polled and black.

The Africander experiment at Jeanerette is of more recent origin, and results from crosses are not yet available. However, Africander bulls have been used rather extensively as sires in cross-breeding experiments with Shorthorn, Hereford, Devon, and Brahman cows on ranches in southern Texas. Several hundred cross-bred calves have been produced from such matings. The cross-breds from the Shorthorn cows have been very promising as calves and yearlings, possessing excellent beef conformation and a deep red color. Cross-bred calves from the Hereford cows have shown great uniformity in type, conformation, and color markings, and have responded well to feeding in the dry lot. It is too early as yet to draw final conclusions as to the value of the Africander for the development of hybrid strains, but from the information already at hand it appears that hybrids having Africander blood possess a greater degree of smoothness than the hybrid types carrying Brahman blood.

SOME PROPOSED RECORD-OF-PERFORMANCE TESTS

It must be admitted that although genetic analysis of beef characters cannot proceed until the proper methods for measurement are developed, it is by no means certain that when this advance has been made the immediate trend will be in the direction of developing new types through the application of genetics. There are in the beef breeds today individual animals that approximate almost all that is desired in conformation and quality. The first step, logically, would be the widespread use of the measurement methods to locate strains that are producing such animals, and then from this nucleus to develop improved strains that will reproduce the high quality uniformly. Both in the sifting-out process and in the subsequent development of improved strains, some record-of-performance scheme will be necessary to furnish the data required as a basis for selection.

A record-of-performance test for beef cattle should include some live-animal measure that indicates quality of carcass, in addition to rate of gain, efficiency of feed utilization, and reproductive ability. Rate of gain and efficiency of feed utilization are rather closely associated on the average, but, for cattle in general, quality of carcass is largely independent of either. It is of the greatest importance, therefore, that the test include an accurate evaluation of carcass quality.

Suggestions for record-of-performance tests have been made by Winters (1920, 1930, and 1933); Winters and Peters (1931); Holbert (1932 and 1933); and Sheets (1932). All of these were discussed by Winters in Technical Bulletin 94 of the Minnesota Agricultural Experiment Station. The test proposed by Holbert is based entirely on show-ring winnings of the sires and their offspring. It should be effective in singling out the strains within a breed that have been the most consistent in winning prizes, but it falls far short of supplying the information required for determination of intake and output of the beef animal. The other suggestions are in general quite similar to one another but differ in detail. The plan suggested by Sheets, based on research conducted by the Department of Agriculture, includes: (1) The gain in weight from birth to slaughter, (2) record of all feed consumed from birth to the end of the fattening period, and

(3) a slaughter score based on dressing percentage and the physical and chemical characteristics of the cooked meat.

In the scheme advanced by Winters and others, average daily gain is used in place of total feed consumed to measure efficiency of feed utilization. This makes the scheme much easier to apply on a wide scale and at a low cost. Differences in conformation are taken care of by scores made by a committee. Such scores, however, tend to have the same faults as show-ring judging. The values assigned to the various points are arbitrary and the total evaluation they give is really an estimate subject to errors of judgment and uncertainty in appraising the relative importance of different characters. The method is not a mathematical measure. However, it is the best that is available for use at the present time and possibly gives an approximation of actual conditions.

Tests Show Wide Variations in Offspring

In record-of-performance tests conducted to locate superior breeding animals it is important to observe that the uniform transmission of superior qualities is most important. An individual may exhibit many superior qualities in the test, but unless these qualities are transmitted with uniformity to offspring, the animal is not a superior breeding animal.

Research conducted by the United States Department of Agriculture with record-of-performance tests on Shorthorns has shown very wide variations in growth rates, amounts of feed consumed per hundred pounds of gain, and carcass grade. The range in feed consumed per hundred pounds of gain for all calves tested was 304 to 473 pounds, a difference of over 60 percent. The range in age at which a live weight of 900 pounds was reached was 373 to 566 days, a difference of more than 50 percent. Carcass grades showed a range between 75 and 85 points. These data include calves by several sires. The results show rather wide variations even among calves by the same sire. In one case, two full brothers were 373 and 464 days old respectively at 900 pounds. As might be expected, there is far less difference between averages for different sires than there is between the best and the poorest individual performer from each sire.

The range of performance relative to growth, efficiency in the use of feed, and carcass grades for the calves from different sires shows much overlapping, and in the preliminary stages of the investigations no sire has been found that stands out significantly from all others for superiority of offspring in all three characteristics. For instance, the calves of three beef sires, which for convenience may be designated A, B, and C, were fed out on the record-of-performance test to a live weight of 900 pounds. The average results for the three groups were respectively as follows: Age at 900 pounds, A—437, B—475, C—473 days; total digestible nutrients per 100 pounds gain from birth to 900 pounds live weight, A—379.5, B—404, C—381 pounds; pounds of cold dressed carcass per 100 pounds total digestible nutrients, A—17.5, B—15.9, C—17.5; carcass grade, A—77.1, B—83.0, C—80.4.

In other words, the calves of sire A, when averaged, were best in weight for age, gain for feed consumed, and dressing percentage for feed consumed, but poorest in carcass grade.

The calves of sire B were poorest in weight for age, gain for feed consumed, and dressing percentage for feed consumed, but best in carcass grade.

The calves of sire C were second in weight for age, gain for feed consumed, and carcass grade, and equal to A in dressing percentage for feed consumed.

These data are from four, two, and seven calves, respectively, from each sire, and of course they can be considered only as indications of sire differences. This is especially true when one considers that the dams were different in most cases in each group, a point of very great importance which will be discussed below (fig. 7).

These investigations bring to light many experimental difficulties which are important in connection with the development of more practical procedures for record of performance with beef cattle. One of the chief difficulties is that nearly all of the tests are made on steer calves, and hence the most efficient feeders and those having the highest carcass grades cannot be used for breeding to see whether they will pass on their superiority. When a superior sire is found he must be used again in order to obtain sons and daughters for use in breeding the next generation. The sons and daughters of a superior breeding animal must be similarly tested by progeny performance to determine those that transmit the desired qualities. This is especially difficult in beef cattle because animals on which the test is based have been slaughtered and the number of progeny from a female is limited. Suggestions for overcoming these difficulties are presented in the following section.

The Problem of Testing the Dam

When a superior sire is found, he should be mated with cows which themselves show high levels of development in the characters the breeder wants to intensify. Just as a proved dairy sire would be mated to high-producing cows, so should high-producing beef bulls be mated to high-producing cows. It becomes increasingly apparent that a background of records for both males and females must be built up which can be used in making matings and as a basis for parent-offspring comparisons. Until this advance has been made, the genetic program cannot advance materially.

There is one practical difficulty here which must be overcome. The record-of-performance feeding test as now conducted is not a practical procedure for developing beef-cattle breeding stock, as breeders consider it poor management to feed developing breeding stock too heavily. This difficulty may be overcome to some extent after further study has been made of performance at different ages. In this connection, the wide variations among steers by the same sire indicate that it would be necessary to make a test on all bull calves if the best one is to be selected. Naturally if any selection is practiced, such as keeping the most superior-looking bull calves for future sires while the remainder of the male calves are castrated and used in record-of-performance tests, the results will be unsatisfactory because one would be dealing with a selected population. The ideal method would be to obtain information on the growth, feed utilization, and conformation characteristics of each calf dropped. This would furnish a basis for judging the real breeding worth of parents.

From the breeding standpoint, a major difficulty lies in the fact that at present there are only limited data on the performance of beef dams comparable to the milk records of dairy cattle. Since the dam contributes half the inheritance to each offspring, it is necessary that

FIGURE 7.—Rib cuts from two record-of-performance Shorthorn steers sired by the same bull but out of different cows. The steer represented in *A* (no. 74) required 417 days to reach 900 pounds, while that in *B* (no. 76) required 520 days. However, the carcass grade for the latter was 85 points as against 79 for the other.

something be available on which to judge the quality of this inheritance if the breeding program is to be effective. The really superior sire is the one able to raise the production of his offspring over that of the dam—production in this case being measured largely by efficiency of feed utilization and carcass quality. The dam must be rated, then, if the offspring is to be compared with her.

Naturally carcass quality cannot be measured for the dam without slaughtering her, but it can be at least approximated by grading the live animal. The results of extensive studies conducted by the United States Department of Agriculture have shown that the correlation between the grade of the live animal as a feeder and carcass grade is 0.69. As this is a fairly high correlation, the carcass grade can be estimated from the animal grade with some accuracy.

The dam's feeding efficiency can be obtained if facilities and expense will permit. In this case also there is readily obtainable data that will give an approximation of feeding efficiency. It is well known that rate of gain and efficiency of feed utilization are very closely associated, and, as indicated by Winters at Minnesota, rate of gain probably can be used to replace actual measurement of feeding efficiency in many cases.

It is apparent, then, that if rate of gain from birth to some definite live weight is known, and a live-animal grade at that weight is available, these would furnish a workable basis for a breeding program that could include daughter-dam comparisons. Of course, all the animals would necessarily have to be maintained in essentially the same environment and receive the same kind of feed or results would sometimes be misleading.

Limitations Versus Possibilities

When considering such a system, the fact must not be overlooked that it is merely a refinement of the system already being followed by progressive breeders. The animals that gain most rapidly and possess the best conformation are the ones most likely to attract the breeder's attention and to be selected for breeding stock. This procedure has naturally culled the beef populations to a considerable extent, and the culling will reduce the rapidity with which further progress can be made even when a process involving certain refinements is applied. Also, one must not expect to eliminate all variations in rate of gain, efficiency of feed utilization, and carcass grade by the application of genetic principles, because heredity is only one of the factors affecting variation in such characters. Genetic research with smaller animals, conducted over long periods and involving many thousands of individuals, has demonstrated the fact that even when strains are made homozygous in all respects, not over 50 percent of the variations in gains and live weight is eliminated.

At the same time, such research has clearly demonstrated that strains or families—as distinct from individuals—differing very greatly in growth and live weight can be developed, and their differences from one another can be held over long periods. It may be surmised from this result that, since strains differing significantly in growth rate can be established, it would also be possible to establish strains differing in efficiency of feed utilization. This question has been investigated with laboratory animals in Minnesota, where it was shown that selective breeding was effective in establishing strains of rats which differed

significantly in their efficiency in feed utilization. The experiment shows that efficiency of feed utilization is affected by heredity and can be significantly changed by the application of genetic principles.

Similar results can be accomplished with cattle if the correct breeding procedure is followed and data are available for the breeder to use in making his selections. Establishing strains that differ uniformly in rate of growth and feeding efficiency, so that their performance in these respects could be predicted and relied on, would be a long step forward. The correct breeding procedure is fairly well established. Lack of data is the missing link that must be supplied, and naturally the data must be of the right sort.

The research already referred to is being conducted to develop an adequate record-of-performance procedure. In its initial stages, the program naturally must go into great detail and explore many methods that may turn out to be impractical in an endeavor to ascertain the biological principles underlying the development and expression of the characters that are important to the breeder, the packer, and the ultimate consumer. When the basic facts are known, the way will be open for simplification and practical application.

Some Problems of the Breeder of Dual-Purpose Cattle

THE most important problems of the breeder using the dual-purpose class of animals center around the question of an ideal and the significance of variations from this ideal. In general terms, the ideal is a breed, or a strain within a breed, that can produce fairly good beef and enough milk to make it profitable to milk the cows.

The dairy part of the ideal is usually defined as the production of cows that will give 8,000 to 10,000 pounds of milk a year when milked twice a day, with good farm care and feeding. The beef part of the ideal is not at all well defined, although it is usually spoken of as the ability to produce a beef carcass that will grade Medium to Good. It is not intended that the two objectives should be realized simultaneously; that is, the cow that is giving large quantities of milk is not expected to be good material for the butcher at the same time, but it is intended that she shall possess the muscular basis and the physiological aptitude for converting her feed into beef when the stimulus for turning it into milk has ceased, and that her sons shall be able to make reasonably good beef economically.

The dual nature of such an ideal is not unique. All animal breeding—and plant breeding as well—involves striving for several different kinds of characteristics in one organism. Sometimes two characteristics are not associated. Sometimes they have something in common, in which case they are more easily attained than if they are in no way associated. Sometimes they are antagonistic to each other and the full attainment of both is difficult or perhaps even impossible.

It is well known that some beef cattle give considerable amounts of milk. There are members of dairy herd-improvement associations in some States who have Hereford or Aberdeen-Angus rather than

dairy cattle, and many who have Shorthorns. Even the farmer who is concerned strictly with dairying derives some revenue from the sale of his cull cows for beef and occasionally raises his steer calves past the veal stage. The farmer with dual-purpose animals occupies an intermediate position in the amount of revenue he expects to derive from each source, and of course in the emphasis he lays on the different traits on his ideal.

Of course, in giving milk a place in the ideal, the breeder automatically gives beef relatively less importance. He has to compromise at times, and because of low milk production must sometimes cull an animal that a beef man would retain. There is nothing unusual in this. Every livestock breeder often has to compromise if he has more than one object in mind. He must always accept imperfections of one kind or another because he never can find enough perfect animals to make up his entire herd. This last consideration would not be a drawback to the geneticist. He would be free to search for a true-breeding combination of characteristics without being confined by the necessity of maintaining a herd of definite size.

DIFFICULTIES IN THE DOUBLE IDEAL

What makes the position of the practical breeder of dual-purpose cattle difficult is that he has on both sides of him beef men or dairy

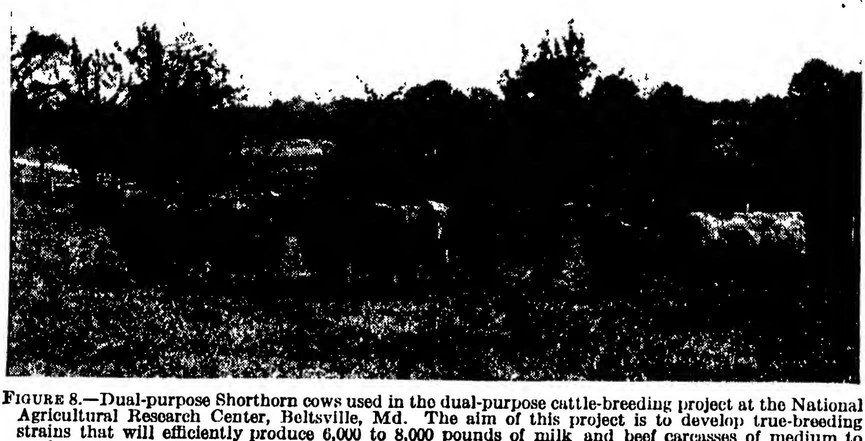


FIGURE 8.—Dual-purpose Shorthorn cows used in the dual-purpose cattle-breeding project at the National Agricultural Research Center, Beltsville, Md. The aim of this project is to develop true-breeding strains that will efficiently produce 6,000 to 8,000 pounds of milk and beef carcasses of medium to good quality.

men who, because their ideal is more nearly a single one than his, can each progress faster in the chosen direction than he can, compelled as he is to do in some measure what they both do. He is trying to keep up not with one but with two Joneses. Also there may be some physiological incompatibility between ability to turn feed into milk efficiently at one time and into beef at some other time, particularly in the case of strains yielding 8,000 to 10,000 pounds of milk. Furthermore, lean meat cannot be fed onto a mature animal to any extent; the inherent factors for beef production must be a part of its germ plasm. The cow that makes first-class cow beef in her old age, or produces steers that make good beef

animals, must all her life carry more muscular tissue than is necessary to make her an efficient high-producing milk cow (fig. 8). The extent to which this extra load of muscular tissue may be incompatible with the production of large quantities of milk is a question that needs more careful investigation than it has yet received.

With dual-purpose animals, special attention needs to be given to the changes that occur during development. As Hammond in England has pointed out, the ratio between muscle and bone changes as age increases. Even at birth, the beef calf has a higher proportion of muscle to bone than a dairy calf. As the two grow older the ratio changes, but the gap remains very great even at maturity. This gap can be lessened to some extent by feeding the dairy calf on a high level and the beef calf on a low level of nutrition, but even so the effect of heredity is usually too great to permit them to reach the same ratio.

Among Shorthorn cattle, the difference in conformation at birth between a calf from a beef strain and one from a milking strain is less than that between a true beef-type calf and a true dairy-type calf. However, a slight difference between the calves of beef and milking Shorthorns is usually apparent, particularly when the latter are from strains noted for high milk production. In fact, even when calves from high-milking strains are developed on a ration that favors growth of frame, they cannot be expected to produce carcasses that are as well finished in the yearling class as those of true beef calves. If carried to a greater weight, however, they might more nearly approach Prime carcasses. Possibly by careful attention to feeding, some of the deficiencies in conformation possessed by the dual-purpose animal from the beef standpoint can be overcome and better carcasses produced. It is not expected, however, to obtain beef carcasses as good as those produced by the best beef strains.

DRAWBACKS OF THE FLEXIBLE SYSTEM OF MATING

Research by Wright and McPhee on Shorthorn history has shown that ability to produce large quantities of milk has cropped out from time to time in various blood lines of the breed. The modern dairy Shorthorn strains are groups selected for milk production, but without being any more closely related to each other than random-selected animals of the breed. The Milking Shorthorn cow, in fact, traces back through beef ancestry to about the same extent as the average beef cow. Apparently there has not been any fixation of combined milk-and-beef-producing ability that would result in a stabilized group.

This is not entirely due to the difficulty of fixing these qualities in combination; in part, it is the result of following a flexible system of mating in order to accomplish this. Even at the present time there are many dual-purpose cattle breeders who attach more importance to dairy performance and less to beef performance than others. This leads to a diversity of ideals within the breed. There is a distinct tendency to concentrate on only one of the two important characters at a time, and while this is being done the animals get too far away from the other character. Then a correction has to be made by introducing new blood lines strong in the second character. Thus there is a swing from one extreme to the other.

The lack of an accurate measure for fleshing is without doubt the most important factor in this situation. Since the breeder has records only for the milk character, the tendency is to concentrate on that. The beef character then gets so far away from him that it is a difficult and slow process to bring it back. If he could measure beef character more accurately and readily, he could use this ideal more consistently in his operations.

RESULTS OF THE SURVEY OF IMPROVEMENT

The survey of improvement in dual-purpose cattle was made with a combination of the methods used for beef with those used for dairy stock. Survey forms of both kinds were forwarded to each of the State agricultural experiment stations with a request that both be filled out as far as possible and that a list of dual-purpose cattle breeders possessing superior stock be submitted.

Only five States reported any experimental work with dual-purpose cattle and nearly all of this was in cooperation with the Federal

FIGURE 9.—This dual-purpose Shorthorn cow illustrates the difficulty of combining fleshing ability with high milk production. Although she possesses excellent beef qualities and her line showed promise of high milk yield, she produced only 4,250 pounds of milk in a year.

Bureau of Animal Industry. Only 10 States submitted names of dual-purpose breeders, and the total number of names was only 18. Obviously when one considers the number of breeders of Milking Shorthorn, Red Polled, and Devon cattle, this number is a very small sample.

However, at the present time no one can say how nearly it comes to including all the breeders who have animals that are uniform in their inheritance for both milk and beef production. The only data that such breeders have to submit consist of milk records. Since the purpose of the survey is to locate animals carrying factors for both characteristics, the possession of records for only one of them is highly unsatisfactory. It is easy to locate high milk-producing animals in the dual-purpose strains, but unless the records are accompanied by

some evaluation of the fleshing qualities of the animals, they merely tell the dairy part of the story. For this reason, the survey of stock in the possession of dual-purpose breeders has been held in abeyance for the time being, pending the development of some method of measuring meat values.

A PROMISING PROGRAM OF RESEARCH

Research to obtain such information has been initiated in the cooperative investigations with dual-purpose cattle carried on by the United States Department of Agriculture and the Minnesota, Nebraska, Indiana, and Florida Agricultural Experiment Stations. The studies include Shorthorn, Red Polled, and Devon breeds. The major problem considered to date is the perfection of some method or methods which will make possible an accurate evaluation of fleshing qualities in cattle. When this has been done, a breeding program for the fixation of heredity affecting both meat and milk production is to be undertaken.

At Beltsville, Md., the Department's dual-purpose herd of Shorthorns has been subjected to a record-of-performance test to obtain necessary basic information on the variations in growth, efficiency of feed utilization, and carcass quality, as well as in milk production. Steers sired by several different bulls have been fed to 900 pounds live weight on the same feeds and under the same conditions as beef calves discussed in the beef-cattle section. Also, similar carcass and slaughter data have been obtained.

Results from calves by four different sires are now available, and, as in the case of beef calves, they show great variation. The number of steer calves in each sire group was 3, 12, 3, and 2, respectively. This number is rather small for sire comparisons to be made at this time. In the case of the sire with 12 steers on test, the calves showed remarkable variation in all characteristics. For instance, the most efficient calf consumed 347 pounds of digestible nutrients per 100 pounds of gain, whereas the least efficient required 592 pounds per 100 pounds of gain. The calf making the fastest gains reached a live weight of 900 pounds at the age of 415 days, whereas the slowest-growing calf required 616 days to reach this weight. Obviously, with such a wide range, the average performance of calves by different sires does not mean much as yet, particularly in the absence of any data that would make possible daughter-dam and sire-son comparisons. These data will soon be available in this herd, however, and the experimenter will be in a position to select matings on the basis of the performance of the parents as well as that of their offspring.

In the group of 12 calves there were 6 that had exactly the same carcass grade, 68.9. Among these, the ages at 900 pounds live weight were 435, 443, 481, 492, 500, and 533 days. The pounds of digestible nutrients consumed per 100 pounds of gain were 407, 347, 394, 398, 420, and 490, respectively. While it appears in general that the efficiency of feed utilization follows the rate of growth quite closely, there are some exceptions.

Among the dual-purpose steers on test there was one pair of full brothers which grew at almost exactly the same rate and showed almost identical feeding efficiency, but produced carcasses grading 68.9 and 75. Another steer calf out of the same dam but by a different sire also produced a carcass grading 68.9, but required 2

months less time to reach 900 pounds and consumed 80 pounds less digestible nutrients per 100 pounds of gain than did either of his half brothers. Whether this difference in feeding efficiency is due to inheritance from the second sire or is only a chance variation is not known, but the case certainly indicates the need of further genetic experimentation to clear up the point.

When Does Superiority Become Evident?

IT IS APPARENT that considerable time would be required before the experimenter would be in a position to know what advance can be expected from selective breeding on the basis of feed utilization and carcass quality, even if accurate measures of these characters were at hand. At the same time, it is also evident that there can be no definite progress toward an ideal type until the ideal has taken some physical form. A step in this direction has been taken by the American Shorthorn Breeders Association. They have constructed models of ideal animals based on the characteristics of outstanding individuals in the breed.

In the development of standards, it is apparent that careful consideration must be given to characteristics at different stages of development, because the breeder's desire is to obtain an indication of superiority at as early an age as possible. He feels that he cannot afford to grow out the bull calves and to keep all the heifer calves until they have produced offspring—yet this is the procedure often required by the science of genetics. For economic reasons it is highly desirable that some practical measure which will serve as a basis for culling young stock be made available. In order to obtain information on this point, practically all of the calves dropped in both the beef and dual-purpose Shorthorn herds at Beltsville have been measured at definite periods throughout their development. It is too early as yet to say what these data will yield; but they furnish a necessary background for determining the relationship between growth and performance at one age with that at another, and eventually they will show at least the limitations, for the purpose the breeder has in mind, of data taken at various stages of development.

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Appendix

Table 1.—*Color genes in cattle and a brief summary of their effects* [1]

Dominant gene	Color of animal	Recessive gene	Color of animal
C	Pigment	*c*	Albino (no pigment).
B	Black hair, black pigment in skin, hoof, tongue, etc., in absence of white-spotting gene *s*.	*b*	Usually red.
Bs	Black spotting, as in Jerseys and Ayrshires. There are multiple-factor modifiers of black spotting. Much black dominant in males and little black, dominant in females.	*bs*	No black spotting.
Br	Brindle—causes black (*Bs*) to form in stripes on a background of red. No effect in an animal with the gene *B*, which is epistatic, that is, covers up the brindle characteristic.	*br*	Not brindle.
D	Dilutes black to dun and red to yellow color	*d*	No dilution.
I	No dilution	*i*	Dilutes black to dun and red to yellow color.
N	Hair of any color becomes devoid of color or white. Heterozygote, *Nn*, is a roan.	*n*	Some pigment.
Rm	No effect on color	*rm*	Changes roan to red.
Wn	Pigmented hair	*wn*	White (Affects hair but not skin. Silver gray of Nellores cattle of Philippines.)
W	Lack of whitening	*w*	Whitening, causing white muzzle and whitish hairs in ears, on the belly, udder, and inside of rear legs; sometimes extends over whole body.
Ps	Black-pigmented skin spots (most easily seen on nose or udder). May occur anywhere on body.	*ps*	Absence of black skin spotting.
Wp	White spotting. Found in English white park cattle.	*wp*	Lack of dominant white.
In	White spotting in the inguinal region	*in*	Absence of white spotting in the inguinal region.

SPOTTING SERIES OF MULTIPLE ALLELOMORPHS

SH	Hereford whiteface pattern		See *S* and *s*.
S	Self-colored (entirely pigmented)	*s*	White spotting in coat and unpigmented areas.
SD	Dutch Belted pattern. Allelomorphic to and dominant over *S* and *s*.		See *S* and *s*.
SC	Causes dominant white-spotting color-sided pattern. Allelomorphic to *S* and *s*, incompletely dominant to *S*, completely dominant to *s*.		Do.

[1] Mostly from Ibsen, H. L. CATTLE INHERITANCE. I. COLOR. Genetics 18: 441–80. 1933.

TABLE 1.—*Color genes in cattle and a brief summary of their effects*—Continued

MODIFIERS OF SPOTTING SERIES

Dominant gene	Color of animal	Recessive gene	Color of animal
Rn	Red-neck—modifier of *SH* (and *s*), causing dorsal portion of neck and shoulders to be red.	*rn*	Absence of red-neck color.
Re	Modifier of *SH*, causing red hair around each eye.	*re*	Absence of red hair around eyes.
Lw	Modifies white spotting to produce little white in coat, tongue, nose, etc.	*lw*	Increased amount of white.
Pl	Modifies *s* to produce little or no white below the knees. Pigment starts at hoofs and works upward.	*pl*	Almost entirely white below knees.

Some Workers Identified with Beef or Dual-Purpose Cattle Improvement at State and Federal Agricultural Experiment Stations

Alabama, Auburn: J. C. Grimes.
California, Berkeley: G. H. Hart, P. W. Gregory, H. R. Guilbert.
Colorado, Fort Collins: G. E. Morton, H. B. Osland.
Connecticut, Storrs: H. L. Garrigus.
Florida, Gainesville: A. L. Shealy.
Georgia, Athens: M. P. Jarnagin, F. R. Edwards.
Hawaii, Honolulu: L. A. Henke.
Idaho, Moscow: C. W. Hickman.
Illinois, Urbana: H. P. Rusk, R. R. Snapp, E. Roberts.
Indiana, Lafayette: F. G. King, H. J. Reed, E. E. Van Lone.
Iowa, Ames: P. S. Shearer, C. C. Culbertson, J. L. Lush, J. H. Bywaters.
Kansas, Manhattan: C. W. McCampbell, H. L. Ibsen, A. D. Weber.
Kentucky, Lexington: E. S. Good.
Louisiana, Baton Rouge: J. B. Francioni, M. G. Snell.
Massachusetts, Amherst: V. A. Rice, R. W. Phillips, C. H. Parsons.
Michigan, East Lansing: G. A. Brown, G. A. Branaman.
Minnesota, St. Paul: W. H. Peters, L. M. Winters, R. E. Hodgson.
Mississippi, State College: E. W. Sheets, R. H. Means.
Missouri, Columbia: E. A. Trowbridge, F. F. McKenzie.
Montana, Bozeman: D. W. Chittenden.
Nebraska, Lincoln: H. J. Gramlich, R. R. Thalman, E. M. Brouse.
Nevada, Reno: F. W. Wilson.
New Mexico, Mesilla Park: J. H. Knox.
New York, Ithaca: R. B. Hinman.
North Carolina, State College Station, Raleigh: E. H. Hostetler.
North Dakota, State College Station, Fargo: E. J. Thompson, V. T. Sander.
Ohio, Columbus: Paul Gerlaugh, C. W. Gay.
Oklahoma, Stillwater: W. L. Blizzard.
Pennsylvania, State College: F. L. Bentley.
Tennessee, Knoxville: M. Jacob, L. R. Neal.
Texas, College Station: J. M. Jones, D. W. Williams, B. L. Warwick.
Utah, Logan: E. J. Maynard.
Virginia, Blacksburg: R. E. Hunt.
West Virginia, Morgantown: E. A. Livesay, C. V. Wilson.
Wisconsin, Madison: L. J. Cole.
Wyoming, Laramie: F. S. Hultz.

United States Department of Agriculture, Bureau of Animal Industry, Washington, D. C.: W. H. Black, E. W. McComas, and Bradford Knapp, Jr.

Field stations:
- Brooksville, Fla., W. F. Ward.
- Tifton, Ga., B. L. Southwell.
- Jeanerette, La., C.W. Edwards.[1]
- Beltsville, Md., A. C. Cook.

Field stations:
- Miles City, Mont., J. R. Quesenberry and A. L. Baker.
- Middlebury, Vt., E. B. Krantz.
- Lewisburg, W. Va., R. H. Tuckwiller.

[1] Deceased

Swine—Some Current Breeding Problems

By H. C. McPhee, Chief, Animal Husbandry Division, and O. G. Hankins, Senior Animal Husbandman, Bureau of Animal Industry

THERE has recently been a marked awakening in the United States to the need for coordinated breeding research on swine characteristics of economic importance. Also there has been a growing realization among breeders and others that something more than records of ancestry, litter size, and show-ring winnings is required as a basis for truly effective selection of breeding animals. This article, which is not intended in any sense as a complete treatise on swine breeding, is written with that viewpoint in mind. The situation challenges the best thought and effort in the industry and in research institutions.

In connection with the cooperative survey of plant and animal improvement, questionnaires asking for information on swine improvement were sent to the agricultural experiment stations in each of the 48 States. These questionnaires were composed of: (1) An introduction explaining the purpose of the survey and asking for information on the system of breeding, nature of active projects, kinds of data being recorded, and a list of breeders whose litters have a reputation for purity of breeding; (2) a swine sire card for litter averages on which space was reserved for data on average birth weight, size of litter, percentage weaned, weaning age, average weaning weight, feeding data, weight for age, and average carcass grade; (3) a sire card for individual record giving space for data to show individual grade on foot, individual carcass grade, and individual carcass measurements; and (4) a supplementary card for data on ration used and method of feeding, conditions of feeding test, health notes, any other environmental conditions which might affect the data being collected, and a special description of sire's progeny. It was planned to send another questionnaire at a later date to the private breeders within each State whose names were listed by the State station as having a reputation for producing animals having superior inheritance.

Results of the Cooperative Survey of Swine Improvement

THE cooperative survey of swine improvement shows that, so far as the agricultural colleges and experiment stations are concerned, there is essentially the same situation in the case of swine as in the case of other farm livestock. In other words, the amount of attention given to swine-breeding problems in these agricultural institutions is limited. Out of 48 experiment stations, only 9 report fundamental breeding projects, and few of these projects are concerned with characters that are important economically. Table 1 shows, however, that 15 States carry on some swine-breeding work, and that 4 others are compiling data on special characteristics in the college herd.

TABLE 1.—*Projects in swine breeding (reported in survey) being conducted by State agricultural experiment stations and by the U. S. Department of Agriculture, together with a list of places where data on particular swine characters are being recorded regularly*

Item	Alabama	California	Colorado	Georgia	Idaho	Illinois	Iowa	Kentucky	Minnesota	Montana	Nebraska	North Dakota	New York	Ohio	Oklahoma	Oregon	South Carolina	Washington	Wisconsin	U. S. Department of Agriculture
Projects:																				
Inbreeding		X					X		X	X					X		X			X
Line-breeding	X			X		X	X				X		X				X	X		X
Outcrossing and outbreeding						X					X	X	X		X		X			
Cross-breeding									X	X										X
Inheritance of gain						X														X
Comparison of breeds							X													
Inheritance of defects					X										X					X
Type				X	X					X		X	X						X	X
Measuring efficiency in pigs									X											X
Inheritance of resistance to disease						X														
Incidental data:																				
Inverted nipples					X									X	X					
Polydactylism		X																		
Stillborn		X																		X
Defective heads		X			X															X
Kinky tails		X													X					
Short or creased ears		X			X															
Hernia			X	X		X	X	X		X			X		X				X	X
Cryptorchidism			X			X	X			X			X		X					X
Cleft palate						X							X		X					X
Swirls			X		X	X	X	X					X							X
Resistance to disease						X	X						X		X	X				
Unusual color markings			X				X				X				X	X				X
Malformed pigs				X																
No rectum								X												
Melanotic tumors					X															
Short toes					X															

On the other hand, the fact that only a small number of stations are now engaged in this work is not in itself a serious matter, because a few stations with proper facilities and personnel should be able to cover the field. The really disturbing part of the situation is the tendency of many of the experiment stations to work independently even though they may be fully familiar with investigations at other institutions. More progress might be expected if a single coordinated

program of research on swine breeding could be set up. Several workers are giving attention to one or more specific problems, and often the experimental work is done with the college herd. It appears that lack of funds, equipment, or personnel, together with the fact that the herds are maintained primarily for purposes other than experimentation, is a great handicap in undertaking the type of research needed.

DATA RECORDED BY EXPERIMENT STATIONS

The swine herds at most of the colleges are maintained to furnish pigs for feeding experiments and as material for demonstrations and class work in judging. The demonstrations and judging at present are included in all agricultural college curricula. It is important, therefore, that the facts be recognized so that there will not be unjust criticism for lack of progress. Much confusion has already resulted from assuming that every institution that spends money to maintain a swine herd should be conducting research projects on some aspect of swine husbandry. As a matter of fact, there are cases where this is not possible because the herd is maintained solely for other purposes.

The cooperative survey previously referred to reveals that the usual plan of breeding in experiment station herds is to select individuals as good as can be found for sires, with some attention—how much it seems impossible to measure—to pedigree. Sows are culled closely for any lack of prolificacy. In selecting young boars and gilts, considerable attention is paid to the average excellence of their litter mates. In some herds very few sows or boars are kept past the yearling age, but in others an effort is made to keep boars and sows producing good offspring as long as this can be done without inbreeding intensely.

Data recorded in addition to pedigree include birth and weaning weights and in most cases some kind of grade for vigor at birth. In a few cases there is a definite system of rating or scoring the whole litter at weaning time. Only a few stations take live measurements and only a few slaughter enough pigs to get carcass grades or measurements on more than a small fraction of those produced.

Other data recorded at only a few stations or on only a few pigs include such things as calcium and phosphorus ratios in the blood (California and Oklahoma); photographs (Wyoming); refractive index of fat, cutting yields, sow's milk production (California and U. S. Department of Agriculture); scores or grades of individual pigs for type, quality, size of frame, health, and details of conformation (California, Iowa, and U. S. Department of Agriculture). Rate of gain to market weight is recorded by many stations, but the data are often difficult to interpret because the pigs are used in different feeding or management experiments.

Weights of the pigs at regular periods and amounts of a standard ration consumed up to a weight of 225 pounds, plus extensive observations on the carcasses and meat, are taken on many of the pigs from the Department of Agriculture herd at Beltsville, Md., and on some pigs at the Iowa and Minnesota Agricultural Experiment Stations. This is done in connection with studies of ways to measure differences in real or practical merit. Cooking and palatability data are included for many of the carcasses from the Beltsville herd.

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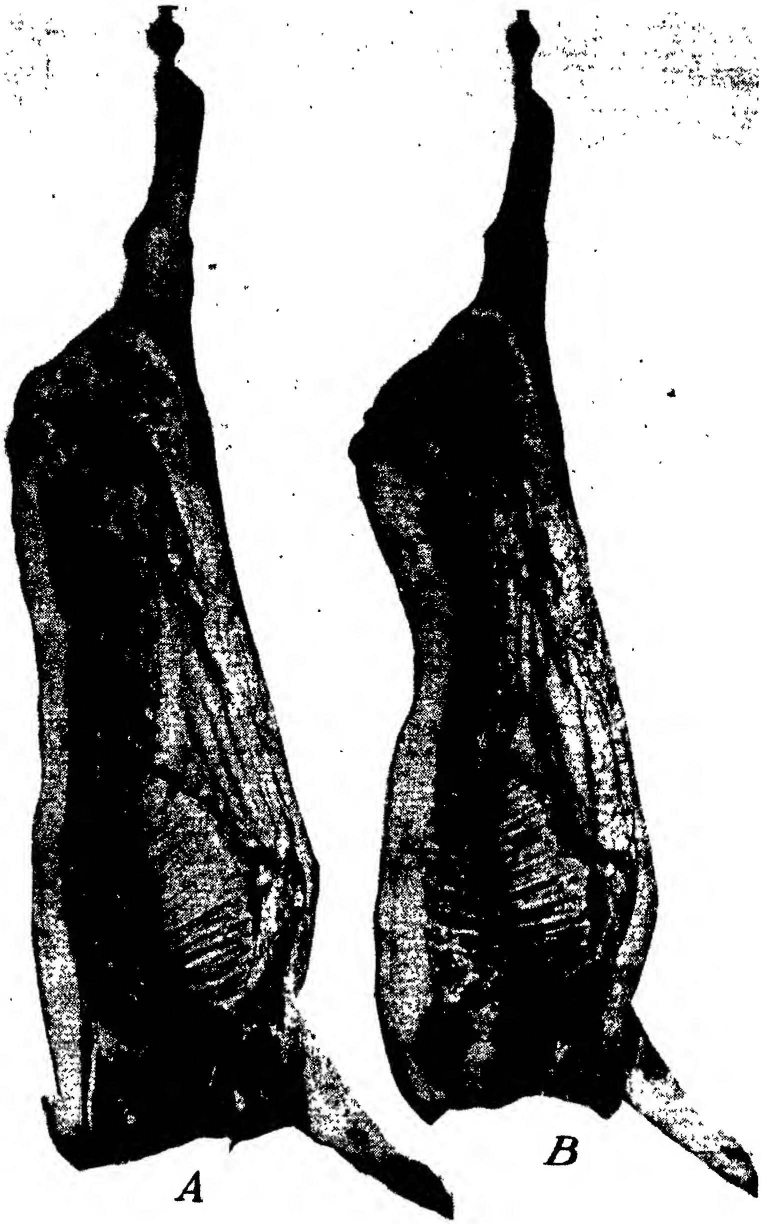

FIGURE 1.—An example of the difference between pigs in the same litter, handled under identical conditions. Although these hogs weighed exactly the same at the close of the experimental feeding period, there were marked differences in the carcasses. The hams from one hog (*A*), weighed 40.5 pounds; those from the other (*B*), weighed 34 pounds; maximum thickness of back fat was 2 inches and 3 inches, respectively.

Although most of the contributions to genetic knowledge in swine breeding have been made by workers using these college herds as material, the arrangement is like putting the cart before the horse. The investigator is forced to do what research he can without interfering with other uses for which the herd is maintained. Only rarely,

under such circumstances, can much material of genetic value be obtained.

It is obvious that this condition is an important factor in retarding progress in swine genetics. There is urgent need for a new experimental set-up so arranged that the investigator can plan his experiments and then obtain the equipment and the animals required to carry on the investigation.

ECONOMIC CHARACTERS RECEIVE LITTLE ATTENTION

Many of the data collected on experimental herds in this country deal with the inheritance of such traits as anatomical abnormalities and characters that disqualify an animal in the show ring. In some cases the work is definitely planned to show the mode of inheritance of the trait dealt with, but in many others it involves merely making a record of the character when it appears in the herd, with the idea of analyzing the accumulated data and, if possible, determining the mode of inheritance from them. The traits mentioned in the survey, some of which are economically significant, include defective skulls; lethals of various kinds; crease in the ear; scrotal, umbilical, and rectal hernias; melanotic tumors; swirls; extra toes; cryptorchidism; variations in belt of Hampshires; white spotting and shade of red in Duroc-Jerseys; roaning; teat pattern; nervous gait; pinched heart girth; cleft palate; kinky tail; prenatal deaths; sterility; and disease resistance.

Characters the inheritance of which is now known are listed herewith:

Characters in swine, the inheritance of which has been determined by various research workers

Dominant	Recessive
Agouti	Nonagouti.
White [1]	Colored.
Black (of Large Black of England), a dilution factor if present, reduces black to a blue gray in F_1 hybrid.	White.
Black	Red.
White belt	Solid color.
Haired	Hairless.
Nonherniated	Hernia.
Testicles descended	Cryptorchidism.
Mule foot	Normal foot.
Erect ear [1]	Lop ear.
Tamworth type face [1]	Berkshire type face.
Wild litter size (4)	Larger litters.
Wooly hair	Normal hair.
Normal	Defective skull.
Normal	Kinky tail (fusion of vertebrae).
Solid color	White spotting.
Hair whorls	No whorls.
Normal	Short rump.

[1] Not always completely dominant.

Research projects dealing with the inheritance of characters of outstanding economic importance are relatively few. The influence of heredity on rate of gain is being studied at the Illinois Station, and research on methods of measuring feeding efficiency and evaluating breeding superiority is under way at the Iowa and Minnesota Stations and in the United States Department of Agriculture. An important part of these projects is a feeding test in which a selected

sample of pigs from each litter is fed to a live weight of 225 pounds under controlled feeding conditions. The amounts of feed consumed, gains, dressing percentage, and certain carcass characteristics are recorded. From these data, together with data on numbers of pigs farrowed and weaned, the performance or efficiency of each mating is determined.

This work attracted considerable attention when it was started in 1929, but the expense of testing large numbers of litters prevented its continuance on a sufficient scale and for a sufficient length of time to locate and perpetuate strains of uniformly high efficiency and quality. Although the movement was sponsored by the National Swine Growers' Association, and a fairly large number of litters were tested in Iowa and Minnesota and in the Department, this kind of work has received less attention in the States mentioned during the past 2 years.

Projects in Inbreeding and Cross-Breeding Show Interesting Results

ALTHOUGH inbreeding has been used successfully by several swine breeders, notably by the late N. H. Gentry, of Missouri, its value as a means of improving swine did not receive the attention of experiment station workers until fairly recent years. Prior to 1920 only the Delaware Station had given any attention to this subject, but since that time several stations have carried on this type of experiment. Only at the Minnesota, Oklahoma, California, and Iowa Stations and in the Department, however, have strains been carried for a sufficient number of generations to attain a high degree of homozygosity. These are described in some detail later in this article.

The Berkshire inbreeding work at the South Carolina Station resulted in the production of a number of animals that attained prominence in the show ring.

Berkshires were also used for inbreeding at the California Station, where brother and sister matings were practiced for several generations. The most advanced degree of inbreeding reached was 74.00, on the basis of Wright's coefficient. In other words, theoretically three-fourths of the heterozygosity of the foundation stock was eliminated. Apparently there was only slight deterioration in vigor and in size of litter. Type seemed to remain fairly constant and there were no segregations of color or of abnormalities. Unfortunately nearly all the pigs in this inbred herd reacted to the test for abortion disease in 1931, and only one boar and two sows free from infection were saved.

At the Oklahoma Station, Duroc-Jersey hogs have been inbred by half-brother and sister matings for six generations, and attention has been given specifically to rate of growth, efficiency of feed utilization, and type. Among the inbred lots, size of litter, weaning weight, and growth rate have been lower, and feed consumption per hundred pounds of gain and mortality have been higher than in the noninbred check groups. The inbreds also proved to be less efficient in digestion trials than the outbreds. Studies on the blood of the two groups

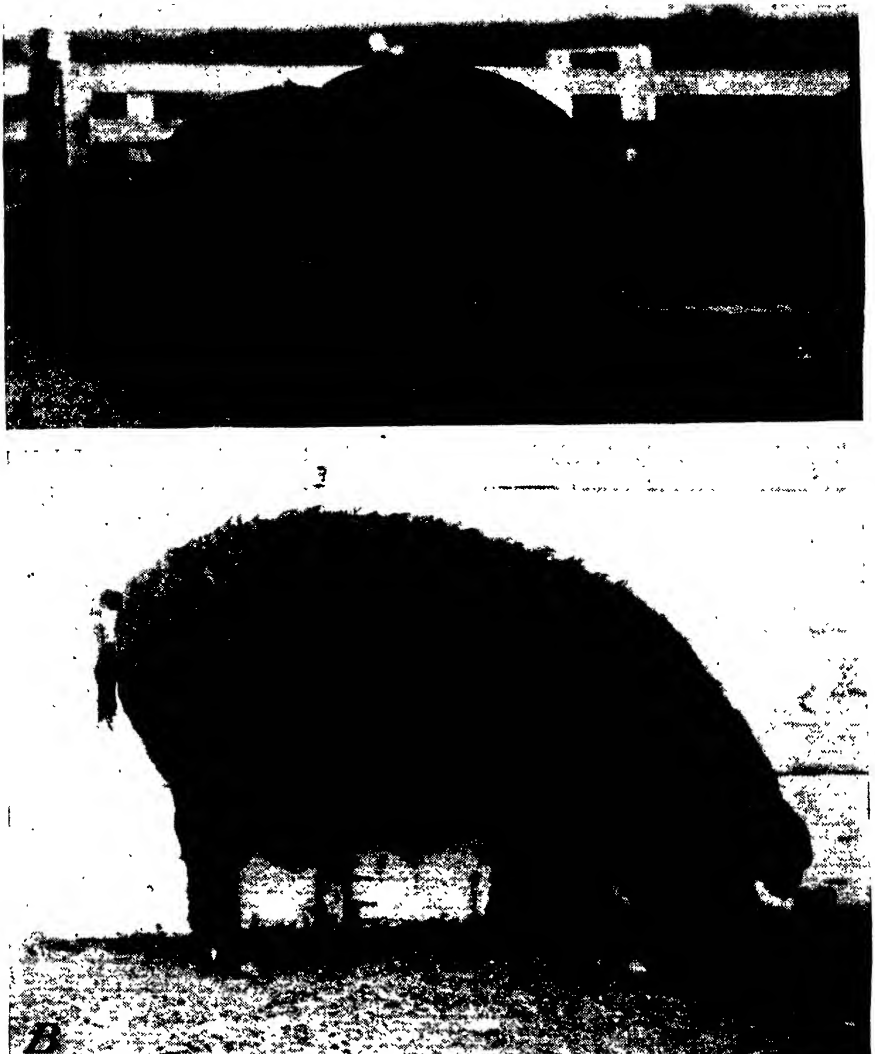

FIGURE 2.—Two of the original gilts (*A*) and a gilt (*B*), showing the type of pig in the sixth generation of continuous half-brother and half-sister inbreeding with Duroc-Jersey hogs at the Oklahoma Agricultural Experiment Station. The curly bristles shown in the sixth-generation individual have appeared frequently, and apparently this is a case of recessive genes being brought to light. Segregations affecting conformation are apparent.

indicate that the inbreds became more anemic during the first 3 weeks after birth and were slower to recover the hemoglobin level found at birth.

The Iowa Station inbreeding experiment, begun in 1930, is with the Poland China breed. Intensity of inbreeding is being held at a level represented approximately by a three- or four-sire herd closed to outside blood, in order that selection may be effective.

At the Minnesota Station full brother and sister matings of registered Poland China swine have been made for eight successive generations without any marked loss of vigor (probably in part because of chance selection of strains free from undesirable recessive characters). The results noted include the following: Disposition is apparently inherited, and some undesirable factors have apparently been segregated by inbreeding. Among the most interesting and perplexing segregations have been odd physiological and psychological sexual reactions. Two lines have been lost because of reluctance to mate, but the difficulty has been overcome in the present inbred lines. Comparisons indicate that segregation of vigor has occurred and that some lack of vigor has been eliminated by selection, so that on the whole no vigor has been lost.

In the Department, full brother and sister matings of registered Poland China, Chester White, and Tamworth swine have been made

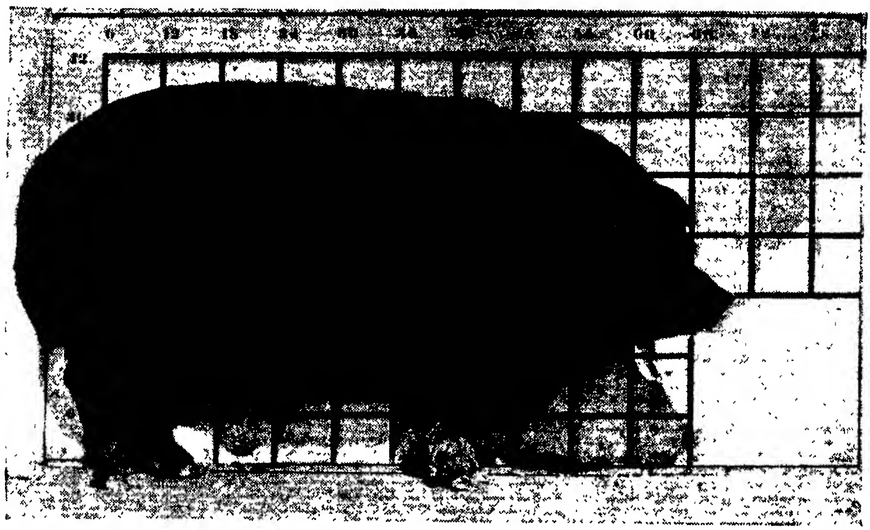

FIGURE 3.—Inbred Poland China boar produced at the Southeast Experiment Station, substation of the Minnesota Agricultural Experiment Station, Waseca, Minn. This boar represents five generations of continuous brother and sister matings.

with considerable variation in results. Two Poland China strains failed to persist beyond the second generation of inbreeding, and many characters segregated out from the matings, including color variations, hernia, cleft palate, and cryptorchidism. One Tamworth strain reached the fifth generation of inbreeding but at that stage was very inferior because of faulty conformation and lack of fertility. Aside from degrees of vigor, the outstanding segregations in the Tamworth strain were swirls and black spotting.

Two inbred Chester White strains have persisted, one of which is in the third and the other in the seventh generation. The most advanced inbred strain has shown a remarkable constancy of vigor in all respects but still shows considerable variation both in type and in growth characteristics. One noteworthy result is an indication of fixation of heredity affecting the plumpness of ham in this strain. It has not been possible at the present stage of the experiment to eliminate all the undesirable heredity, probably because the system of inbreeding is so intense that selection is not entirely effective.

The results of all these inbreeding experiments show four important things:

(1) Pigs are remarkably heterozygous in their heredity for various characters such as color, anatomical abnormalities, conformation, and growth. This is evidenced by the results at Minnesota, where unexpected but very significant segregations of color, temperament, sexual reactions, and vigor occurred. Quite different characters segregated out in the Poland China inbreeding experiment in the Department, including such abnormalities as cleft palate, hydrocephaly, cryptorchidism, and a new recessive color factor. The defective strains, which can persist under a system of outbreeding, should be eliminated from the swine population with the object of raising the average quality of hereditary material within the breed.

It is unfortunate that more attempts have not been made to establish inbred strains. There are two reasons why this should be done: (1) So that strains with factors for undesirable characters in their heredity might show up and be eliminated, and (2) so that strains possessing enough vigor to persist under close breeding might be available for a

FIGURE 4.—An inbred Chester White sow (*A*) with four of her daughters (*B*, *C*, *D*, *E*). This sow is the result of three generations of brother and sister mating. Attention is directed especially to the uniformly excellent development of hams among all five animals.

breed-improvement program. There is no sound reason to believe that other breeds differ materially from the Poland China so far as having many hereditary traits in a heterozygous condition is concerned. In fact the experience of the Department with Chester Whites and Tamworths indicates that a similar condition exists in these breeds. Only one strain of Tamworths out of five and one strain of Chester Whites out of five persisted to the fifth generation of inbreeding. In both breeds segregation of characters for color, vigor, and conformation occurred.

(2) The experience of the few who have dared to try close breeding—four breeds being represented—shows that certain individual pigs have the hereditary basis for sufficient vigor to permit strains developed from them to persist under a system of inbreeding for five or more generations. It is true that in most cases there has been either segregation or loss of vigor, but this fact is not unduly disturbing. Inbreeding is in some respects similar to an automobile race in which cars are driven at 135 or more miles an hour. Neither is safe for the layman, but both uncover inherent defects and merits not obvious to the eye. In experimental work with swine the fear of doing something the farmer cannot afford to do, or producing some pigs of unacceptable quality, has probably been more of a drag to progress than many realize.

(3) In many of the swine-inbreeding experiments a very close system of inbreeding such as brother and sister or parent and offspring matings has been employed. With such an intense system, hereditary characters become fixed rapidly, but the experimenter can do little to direct the destiny of the line by the selection of desirable characters. Bad as well as good heredity becomes fixed, and it may be necessary to go over much of the road again to get rid of the undesirable characters. This has actually happened in one strain of inbred Chester Whites in the Department; the sex-limited genes for cryptorchidism became fixed in an inbred line possessing heredity for superiority in general vigor, feeding efficiency, and conformation. It is doubtful whether the closest forms of inbreeding are advisable except possibly as a technique to identify quickly matings possessing much desirable heredity. The further development and purification of such strains should be pursued with a milder form of inbreeding in order that selection may play a decisive role.

(4) The prevalence of disease is one of the most disturbing factors in the development of closely bred strains. It takes from 5 to 10 years to develop an inbred strain, and if disease then gains entrance to the herd, everything accomplished may be lost. This happened in the California Berkshire experiment, it has occurred in some of the strains developed by the Department, and it terminated the early work of Hayward and Hays in Delaware. With the present widespread occurrence of infectious abortion among the swine of the country, there is always a chance that it will gain entrance to the experimental herd. Therefore it is important that every possible safeguard against disease be provided for animals in breeding experiments, at least until more knowledge is gained concerning the genetics of resistance to disease among animals.

CROSS-BREEDING RECEIVES THE ATTENTION OF EXPERIMENTERS

For a long time farmers have frequently resorted to the use of cross-breeding for the production of market hogs. From time to time several of the experiment stations have crossed breeds of swine to determine the value of this procedure as a means of producing superior animals—particularly animals superior in feeding qualities. In some cases, notably in Iowa and Illinois, double matings have been used in such experiments to avoid possible differences among the sows used as mothers. A sow is mated to a boar of her own breed and to one of another breed at the same heat period, so that part of her litter is cross-bred. The two kinds of litter mates, identified by color, are then compared in feeding experiments. Although there has been considerable variation in the results of such studies, the cross-bred pigs appear to be slightly superior when all characters are considered.

It sometimes happens, however, that crosses between two breeds do not produce superior pigs, and it is apparent from the information available that the results are influenced by the inherent characteristics of the strains used. Presumably, the amount of heterosis or hybrid vigor resulting from a cross is dependent on the genetic make-up of the strains involved. In other words, a wide cross may or may not "nick."

An active project on cross-breeding at the Minnesota Station is interesting in this connection and suggests the possibility of a system of controlled heterozygosis for the production of market swine. In this experiment three breeds are being used, the first-generation hybrids between two of them being crossed with the third breed. In such a three-way cross the hybrid sows have a chance to express the effects of hybrid vigor in the rearing of young, and the offspring have the advantage of additional factors from the third breed.

The results have been favorable from the production standpoint, the cross-bred sows farrowing 20.2 percent more live pigs and weaning 36.2 percent more pigs per litter than purebred sows. The average weaning weight of the litters resulting from the three-way cross has been 60.8 percent more than the average weaning weight of pure-bred litters. Moreover, there has been an appreciable saving in the time required to reach 220 pounds' weight and a small saving in feed consumed per unit of gain.

It would be interesting to know how such a three-way cross between inbred strains of three breeds, or between three unrelated inbred strains of the same breed, would compare with the Minnesota results. In a cross of an inbred Chester White sow and an inbred Tamworth boar in the Department experiments, a litter of 10 pigs showed a very interesting performance. They were exceptionally uniform in conformation and averaged 362 pounds of feed per hundred pounds of gain to 225 pounds' live weight. All the carcasses graded Choice and all were "hard" in grading for firmness. The several inbred strains of different breeds now being developed should make it possible at an early date to determine the value of a three-way cross with inbred strains.

Efforts to Establish Record-of-Performance Systems in the United States

IN 1926 the Department and the State experiment stations in Iowa, Minnesota, Wisconsin, and West Virginia began experiments with a modification of the Danish system of testing performance in swine to ascertain whether this system could be adapted to conditions in this country. The experiments demonstrated that there are wide variations in performance, but economic conditions did not justify continuing the work.

Space permits only a brief discussion of the Danish system. For details of data recorded on the Danish swine pedigrees the reader is referred to figure 5.[2]

The first official testing station in Denmark was established in 1907 to supplement breeding information on fecundity with data on weight for age, efficiency of gain, and carcass quality. Only pigs from recognized breeding centers are eligible for testing. The regulations require that an average of one litter a year for each two sows in each breeding center shall be tested by feeding out a sample of four pigs under standardized conditions. The work has gradually grown so that, starting with one station, five official stations and many "local stations" are in operation at the present time. During the early stage of the testing work there was naturally considerable variation in feeding and management methods, but gradually this has been improved, and at present everything is standardized as closely as possible.

The large volume of data obtained during the period since the initiation of this system shows that significant changes have been effected in the pigs produced. One of the outstanding results of the system has been the change in weight for age, which has been reduced on the average by 1 day per year—that is, the age of pigs at market weight was approximately 17 days less in 1931 than it was 17 years before. Probably some of this improvement has been due to better methods of feeding and management, but even after allowance has been made for such changes there still remains a certain amount of improvement due to breeding.

Before such a plan could be adopted in another country, it would be necessary to give careful consideration to the local conditions existing in Denmark, and particularly to the method of feeding. Denmark is a small country in which dairying is an important industry, and dairy byproducts are used extensively in the feeding of swine. In a large country like the United States, where distances between centers of population are much greater and where there is much variation in the kind of feeds locally available for swine, it would doubtless be necessary to make rather drastic modifications in the Danish system of testing before it could be successfully applied.

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[2] A detailed report on the system, its consequences, and the genetic principles involved appears in a bulletin now in press, with the title "Genetic Aspects of the Danish System of Progeny Testing Swine", in the Iowa Research series, published by Iowa State College.

Some German swine breeders have been using a system of securing performance records since about 1926. Only hogs that have been registered in their respective herdbooks are tested and recorded under the new plan.[3]

Hogs whose performance equals or exceeds certain minimum requirements are eligible for recording in an advanced register. It is evident that entrance in the German Record of Performance is dependent chiefly on the performance of the progeny. Animals cannot be admitted because of individual merit. The requirements are based entirely on ability to transmit meritorious qualities to the progeny, and this is the measure of superior germ plasm in the parents. Summary reports of progress in this improvement program are not available.

> *INBREEDING is in some respects similar to an automobile race in which cars are driven at 135 or more miles an hour. Neither is safe for the layman, but both uncover defects and merits not obvious to the eye. In experimental work with swine the fear of doing something the farmer cannot afford to do, or producing some pigs of unacceptable quality, has probably been more of a drag to progress than many realize.*
>
> *Most of the contributions to genetic knowledge in swine breeding have been made by workers using college herds as material, but the present arrangement is like putting the cart before the horse. The herds are maintained for other uses, and the investigator is forced to do what research he can without interfering with these other uses. Only rarely, under such circumstances, can much material of genetic value be obtained*

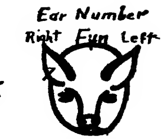
A similar system, known as the East Anglian Pig Recording Scheme, was put into use in England in 1927. Records were not limited to four pigs from each litter, as in Denmark, but might include all the pigs in a litter, and in this respect the records were more representa-

[3]The requirements for sows which are entered for record of performance are as follows: (1) One litter must be farrowed every 8 months at least; (2) 5 litters of the sow must average 10 live, healthy pigs at birth, the smallest litter having not less than 7 live, healthy pigs; (3) at the age of 1 month, litters must average 9 live, healthy pigs, the smallest litter having at least 6; (4) average weight of the litters at 1 month of age must not be less than 132 pounds and the weight of the lightest litter must not be below 99 pounds. The minimum weight of the lightest pig at 1 month of age is 9 pounds; (5) 2 pigs, a barrow and a gilt, from any 2 litters, must be sent to a testing station and fed under supervision until ready for slaughter, and must meet the following requirements: (*a*) Make an average daily gain of at least 1½ pounds during the period when they weigh 88 to 220 pounds, and (*b*) gain at least 220 pounds for each 880 pounds of feed consumed. A boar can be entered for the record of performance when 6 of his daughters have been entered, or when the boar has sired 5 litters from 1 sow and the sow has been entered on the basis of the performance of these litters.

General Marking System

Marking System for Fyn

PEDIGREE of Boar of Land Race, Studbook No.
Born 9/20 1933 at Breeding Center Dybdalgaard, Ringe, Fyn, Denmark
Sold 2/19 1934 to U.S.A. Shipped
Premiums



Animal mark in ear, No.

1. Sire: Sten Lindegaard , Studbook No. Born Mar. 18, 1931 at Breeding Center Honum Owner Premiums (when & where) First at Aarup, Gen. award Odense 1932-33. Exp't meat	2. Dam: No 1 Dybdalgaard , Studbook No. Born Apr. 8, 1930 at Breeding Center. Mariendal Owner Breeding Center Dybdalgaard Premiums (when & Where) First Ringe, Svendb, & Jubilee award (Hojso)

3. Grandsire: Sten Honum Studbook No. 3455 Born 8/29/29 at Breeding Center Honum Premiums: Honor Horsens 1930-31, Skandeb	4. Granddam: No. 48 Honum Studbook No. 13484 Born 5/17/29 at Premiums: First, Horsens 1930	5. Grandsire: Stendys Mariendal Studbook No. 2965 Born 8/2/27 at Breeding Center Mariendal Premiums: Honor Ringsted & Horsens	6. Granddam: No. 6 Mariendal Studbook No. 13458 Born 8/27/28 at Premiums: First Horsens & Skanderborg

7. Great grandsire:	8. Great granddam:	9. Great grandsire:	10. Great granddam:	11. Great grandsire:	12. Great granddam:	13. Great grandsire:	14. Great granddam:
Stendys Mariendal	No. 40 Honum	Finn Honum	No. 37 Honum	Stendys Prima	No. 65 Stendyssegd	Sand	No 78 Mariendal
Studbook No. 2965	Studbook No. 12834	Studbook No 2957	Studbook No. 12326	Studbook No. 2925	Studbook No. 12870	Studbook No. 3179	Studbook No. 11780
Born 8/2/27	Born 7/16/27	Born 2/28/27	Born 1/4/27	Born 6/28/26	Born 5/23/26	Born 9/24/27	Born 1/4/25
At	At	At	At	At	At	At	At
Premium: Honor	Premium: First and Honor	Premium: First	Premium: First	Premium: First and Honor	Premium: First and Honor several times	Premium: First several times	Premium: First

Information on Animals in above Pedigree

Animal and its Family	No of litters	Total number pigs at		Average per litter		Name of Experiment Station	Progeny used in the Experiment																				No. of hogs in Bacon Classes			Remarks
		Birth	Weaning	Birth	Weaning		No. of experimental lot	Date on which lot was [illegible]	Slaughtered No. Boars	Slaughtered No Sows	Shipping Weight ave weight in Kgs	Shipping Weight age in days	Feed units per unit Gain	Percent of exportable meat	Thickness (cm) Back Fat	Thickness (cm) Belly	Length of Body cm.	Average number of points for * Firmness of flesh	Shoulder	Thickness of Back Fat	Distribution of Back Fat	Belly	Hams	Fineness	Fullness of flesh	Bacon type	I	II	III	
2. Dam	6	72	49	12.0	8.1	Elsesminde	370		1	3	90.5	169	3.18	61.9	3.5	3.4	90.5	12.9	12.6	14.0	13.1	13.4	12.6	13.0	13.1	13.0	4			
4. Gd Dam	3	30	30	10.0	10.0	Haraldskjaer	769		4		91.5	190	3.39	60.0	3.7	3.2	91.5	13.1			13.0	12.5	12.5	12.6	12.9	13.1	2	2		
6. Gd Dam	2	25	20	12.5	10.0	Haraldskjaer	793				93.5	167	3.17	59.7	3.5	3.3	91.8	13.1			13.0	13.0	13.1	12.6	13.0	13.1	4			
8. Paternal Gt Gd Dam (Sires side)	5	58	49	11.6	9.8	Haraldskjaer	579		4		91.8	178	3.39	60.6	4.1	3.1	92.6	12.1			12.3	12.0	12.1	12.6	12.3	12.8	3			
10. Paternal Gt Gd Dam (dams side)	7	92	77	13.1	11.0	Haraldskjaer	404		4		90.5	176	3.35	59.3	3.7	3.3	92.3	13.3			13.3	13.4	13.0	13.1	13.0	13.4	4			
12. Maternal Gt Gd Dam (Sires side)	5	56	42	11.2	8.4	Hong	363				91.5	176	3.17	60.5	3.8	3.2	89.0	12.7			12.3	12.7	13.3	12.8	12.5	12.8	3	1		
14. Maternal Gt Gd Dam (Dams side)	8	105	76	13.1	9.5	Haraldskjaer	8				95.6	193	3.54	60.9	4.0	3.3	91.9	13.3			13.1	12.8	12.9	13.3	12.5	13.1	3	1		

*Perfect score = 15.0

FIGURE 5.—A Danish Landrace swine pedigree, showing important performance data.

tive of the bulk of the pigs on a farm than could be the case with the Danish method of sampling. In addition to the weight and counts of litters at weaning time, the weights of all marketable hogs and certain measurements of the carcasses were recorded. The plan was carried on for only 4 years, however, and was then discontinued for financial reasons. Unfortunately, this was too short a period to furnish significant results.

The failure to keep on with the plan emphasizes what is probably the most important factor in swine record-of-performance work or other projects involving private breeders, namely, the great expense involved. The breeder's margin of profit in average times is usually rather small and will not permit his using any system that adds much to the cost of his operations. The problem of financing such testing on a large scale is difficult, but various attempts are continually being made to simplify and cheapen the method without impairing

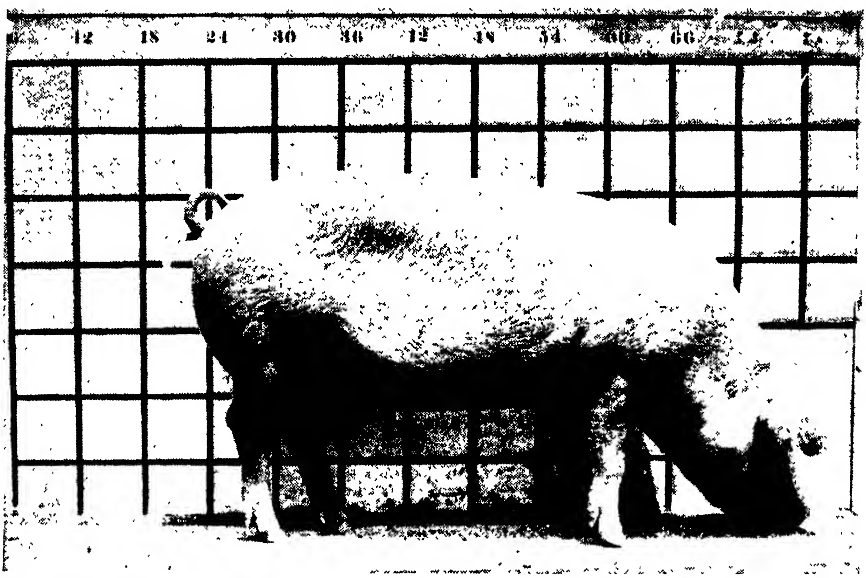


FIGURE 6.—Danish Landrace gilt 10 months old. This animal is the result of years of progeny testing and rigid selection for prolificacy, economy of production, and quality of product.

its usefulness, so that it may be used in some of the principal swine-producing States. The Iowa Extension Service, for example, conducted some county swineherd tests in 1930 and 1931 with this idea in mind. No enterprise of this sort in this country has yet met with outstanding success.

THE DIFFICULTY OF LOCATING SUPERIOR GERM PLASM IN PRIVATE HERDS

The 1930 census showed that there were 357,079 registered purebred hogs and a total of 56,288,000 hogs of all kinds on farms in the United States. It is obvious that the performance of these few registered animals should be recorded, and also the performance of many others that constitute the majority of the swine-breeding stock of the country; but our system of production and recording includes no effective method for identifying truly superior breeding animals.

Because of the lack of results from the survey of experiment station herds, contacts with owners of private herds were postponed pending a more thorough study of the situation and the development of practical methods for identifying superior germ plasm in swine. Breeders as a rule do not maintain records other than those for date of birth of the sire and dam, size of litter, and sex of pigs. Data on weight, measurements of conformation, feed consumption, carcass characteristics, and even on more easily recorded characters such as color and anatomical abnormalities, are exceedingly scarce.

In the development of superior strains of any breed of livestock the breeder naturally turns his attention to locating individual animals which either closely approximate his ideal or which possess one or more characters necessary for the realization of the ideal. By doing this he takes advantage of all past progress and places

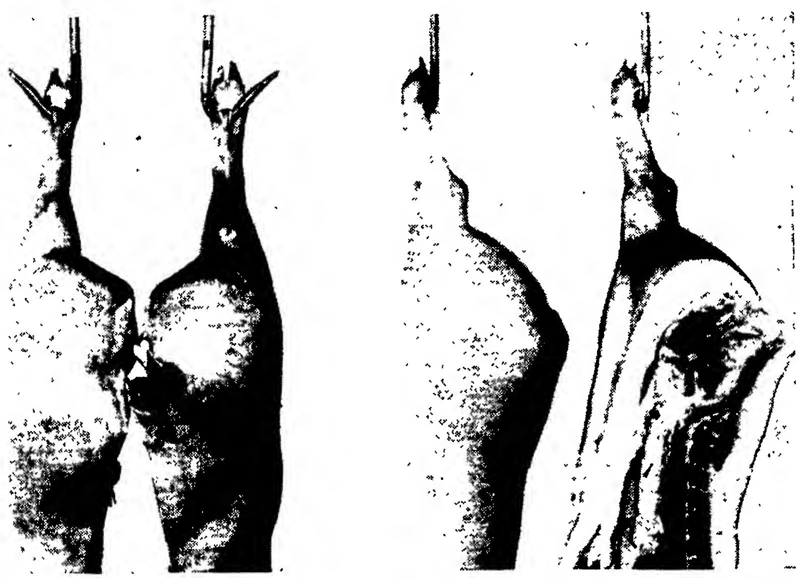


FIGURE 7.—Portion of carcass of a Danish Landrace hog. Marked development of ham and smoothness of side are especially noteworthy.

himself in the most favorable position to bring about further improvement through refinement of the best existing specimens of the breed.

These efforts may include importations of various strains, comparison with present strains or varieties, and cross-breeding followed by close breeding to combine various inherited traits. It is apparent from the methods used that a program of swine improvement should from the start take advantage of all the important advances that have been made in this and other countries. Strains possessing heredity for a high level of fecundity, economical gain, and superior carcasses constitute superior germ plasm, and only by studying them and trying to synthesize new character combinations of economic importance can strains having greater practical value be developed.

Admittedly the location of these foundation animals in this country will be difficult because data are at present so scanty. Application of the Danish system or some modification of it will be necessary to locate animals that carry the heredity necessary for the development of the superior strains.

EXPERIMENTS WITH NEW TYPES FROM DENMARK

Early in 1934 a swine specialist representing the Department of Agriculture and the Iowa Agricultural Experiment Station went to Denmark and selected 8 boars and 16 gilts of the Landrace breed and 2 boars and 4 gilts of the Yorkshire breed from among the most promising and superior strains in Denmark. Each of the pigs has a background of superiority in prolificacy, feed-lot efficiency, and quality of product. It is realized that a part of this superiority is probably due to the feeding system employed in Denmark, and one of the first steps to take with these hogs in the United States is to compare their performance under American conditions with that of American breeds. Such a comparison is being made and it is being

AN active project on cross-breeding at the Minnesota Agricultural Experiment Station suggests the possibility of a system of controlled hybrid vigor for the production of market swine. Three breeds are being used, the first-generation hybrids between two of them being crossed with the third breed. The crossbred sows have farrowed 20.2 percent more live pigs and weaned 36.2 percent more pigs per litter than purebred sows. The average weight of the litters at weaning has been 60.8 percent above that of purebred litters. There has also been an appreciable saving in the time required to reach a live weight of 220 pounds, and a small saving in feed consumed for each pound of gain. It would be interesting to know how such a three-way cross made with inbred strains would compare with the Minnesota results.

accompanied by cross-breeding in an effort to combine the better qualities of the Landrace and Yorkshire with each of several other breeds.

One of the primary purposes of the breeder is to obtain litters of healthy, vigorous pigs conforming to the generally accepted breed characteristics. There are eight major breeds in this country. Six of them are known as lard-type breeds and two as bacon-type breeds. Each has its own breed association—some have more than one—to sponsor the interests of the breed. At one time most of these associations published herdbooks giving parentage, size of litter born and weaned, and sex. In recent years, however, practically all of the associations have found it necessary to cease publication of herdbooks.

If these breed associations could adopt some scheme similar to that used in Denmark, to include data on feed consumed per unit of gain and quality of product in addition to ancestry and litter size, the breeder would have a record of great value to him. At the present time this problem appears to be a financial as well as a genetic one.

Appendix

Some Workers Identified With Swine Improvement at State and Federal Agricultural Experiment Stations

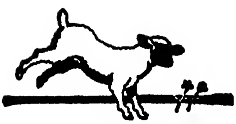
Members of State University, College, and Experiment Station Staffs, Supervising and Conducting Breeding Work with Swine:

Alabama, Auburn: J. C. Grimes, W. E. Sewell.
Arkansas, Fayetteville: E. Martin.
California, Berkeley: E. H. Hughes, P. W. Gregory.
Colorado, Fort Collins: G. E. Morton, H. B. Osland.
Delaware, Newark: A. E. Tomhave.
Georgia, Experiment: F. R. Edwards, Z. A. Massey; Athens: W. S. Rice.
Hawaii, Honolulu: L. A. Henke.
Idaho, Moscow: J. E. Nordby.
Illinois, Urbana: Elmer Roberts, W. E. Carroll, Sleeter Bull.
Indiana, Lafayette: C. M. Vestal, E. E. Van Lone, W. W. Smith.
Iowa, Ames: J. L. Lush, C. C. Culbertson, W. E. Hammond, J. H. Bywaters, F. J. Beard.
Kansas, Manhattan: C. E. Aubel, H. L. Ibsen, D. L. Mackintosh.
Kentucky, Lexington: E. J. Wilford.
Louisiana, Jeanerette: C. I. Bray.
Maryland, College Park: B. E. Carmichael.
Massachusetts, Amherst: R. W. Phillips, C. H. Parsons, V. A. Rice.
Michigan, East Lansing: H. R. Hunt, V. A. Freeman.
Minnesota, St. Paul: L. M. Winters, R. E. Hodgson, E. F. Ferrin, P. A. Anderson, P. S. Jordan, O. M. Kiser.
Mississippi, State College: E. W. Sheets, H. H. Leveck.
Missouri, Columbia: L. A. Weaver, F. F. McKenzie (in cooperation with U. S. Department of Agriculture).
Montana, Bozeman: D. W. Chittenden.
Nebraska, Lincoln: W. J. Loeffel.
New York, Ithaca: J. P. Willman, S. A. Asdell, R. B. Hinman.
North Carolina, State College Station, Raleigh: E. H. Hostetler.
North Dakota, State College Station, Fargo: E. J. Thompson, A. S. Severson.
Ohio, Columbus: W. L. Robison, J. S. Coffey.
Oklahoma, Stillwater: W. A. Craft, C. P. Thompson, J. A. Beall.
Oregon, Corvallis: A. W. Oliver.
Pennsylvania, State College: M. A. McCarty, P. T. Ziegler.
South Carolina, Calhoun: E. G. Godbey.
Texas, College Station: Fred Hale, B. L. Warwick.
Washington, Pullman: Howard Hackedorn.
West Virginia, Morgantown: E. A. Livesay, J. H. Longwell.
Wisconsin, Madison: L. J. Cole, J. M. Fargo.

United States Department of Agriculture, Bureau of Animal Industry

Washington, D. C.: Hugh C. McPhee, O. G. Hankins, J. H. Zeller, E. Z. Russell.
Beltsville, Md.: O. N. Eaton, R. L. Hiner.
Miles City, Mont.: R. E. Hutton.
Georgia Coastal Plain Experiment Station (in cooperation with U. S. Department of Agriculture): B. L. Southwell.

Breeding Problems With Sheep



By H. C. McPhee, Chief, Animal Husbandry Division, and D. A. Spencer, Senior Animal Husbandman, Bureau of Animal Industry

IT IS probable that sheep have been kept by man longer than any other class of domestic livestock. During this long period of domestication, certain breeds with outstanding characters have been developed. The best of them serve their purpose very well. From the practical standpoint there would seem to be less pressure for improvement in the case of sheep than in the case of other classes of livestock. Yet the sheepman would like to produce wool of a given character and quality with greater certainty; he would like to combine this with assured production of good-quality meat; he would like to be sure of getting high-milking ewes for the sake of a good lamb crop; and he is faced with the usual problems of diseases and weaknesses common to other livestock, plus some that are peculiar to his own field. He must consider also, especially, the matter of environment. From hot-house lamb production to the utilization of rugged ranges and of browse and forage unpalatable to most other classes of livestock, the sheep is called upon for a great variety of service to man.

The scientific worker, however, finds himself faced with a very great deficiency in genetic knowledge of practically all the economically important traits in sheep, including wool characters, meat characters, and milk characters. Also many of the available methods for measuring variations in the character and quality of sheep products are either inaccurate or inadequate to detect essential details. These two factors are responsible, to a large extent, for the lack of detailed records among existing flocks. The diversity of ideals peculiar to the American sheep industry—an outgrowth of variable market demands—adds to his difficulties. Under these circumstances, progress will naturally be slow. At the same time, the situation is a challenge both to the scientist and to the forward-looking elements in the industry. Some of the factors in the situation are discussed in this article.

Survey Shows That Most Research Is Concerned with Feeding and Management Problems

IN CONNECTION with the cooperative survey of plant and animal improvement, questionnaires asking for information on sheep improvement were sent to the agricultural experiment stations in each of the 48 States. These questionnaires were composed of: (1) An introduction explaining the purpose of the survey and asking for information on the system of breeding, nature of active projects, kinds of data being recorded, and a list of breeders whose flocks have a reputation for purity of breeding; (2) a sheep sire card for wool on which space was reserved for data on year of birth, animal number, dam number, sex, birth and yearling weights, body type, and yearling fleece data, including number of days of growth, grease weight, clean weight, percentage of grease, length of staple, and fineness; (3) a sire card for mutton giving space for data on year, number, sex, parentage, birth and weaning weights, age weaned, live-animal score, carcass grade, and age slaughtered; and (4) a supplementary card for data on ration, pastures, health notes, and description of experimental methods.

These questionnaires were filled out in part and returned by 24 States. The remaining States either did not reply or returned the blanks with a note that no breeding experiments were being conducted with sheep.

Fifteen breeds were named in the reports for this survey, the more frequent being Rambouillet, Hampshire, Shropshire, and Southdown. Others were Dorset, Oxford, Cheviot, Suffolk, Corriedale, Romney, Ryeland, Australian Merino, Tasmanian Merino, Karakul, and the new tailless breed at South Dakota. Where station and college flocks are not separate, it is customary to keep three to five breeds, but where the station has a separate flock it is often of only one breed and rarely more than two. Often the sheep of the station flock are unregistered or of grade breeding.

The amount and nature of the data submitted varied considerably, as can be seen from an examination of table 1.

TABLE 1.—*Type of data being recorded at the 24 State experiment stations replying to the questionnaire on improvement in sheep*

Kind of data	States recording	Kind of data	States recording	Kind of data	States recording
	Number		*Number*		*Number*
Twinning	16	Fleece weight	19	Face covering	3
Vigor at birth	9	Weight of clean wool	5	Type	2
Weight at birth	14	Length staple	8	Abnormalities	7
Age when weaned	10	Fineness	7	Progeny test	3
Weaning weight	8	Uniformity of fleece	8	Inbreeding	3
Conformation	2	Kemp fibers	6	Line-breeding	5
Live-animal grade	1	Color of wool	2	Cross-breeding	2
Carcass grade	0	Horn character	1		

Grease weight of fleece, notes on number of young per ewe, and birth weight are the items most commonly recorded by the States that sent in reports. Only about one-third of these States regularly record anything on vigor of lamb at birth and weaning age and weight, or on length of staple, fineness of fiber, and uniformity of fleece. Weight of clean wool per fleece is obtained at five stations. Very little attention is being given to recording conformation, live-animal grade, carcass grade, color, type, face covering, and horns. The occurrence of abnormalities is being recorded at seven stations and the presence of kemp fibers in the fleece at six.

In the main, this survey of experiment station practice may be summarized as having the following features:

(1) Most of the research has been directed toward problems in feeding and management, little of it having concerned breeding, except for cross-breeding and the genetics of special traits.

(2) The breeding practices followed have generally been much the same as those used by currently successful sheepmen.

(3) There is much variation in the characteristics measured and in the ways of measuring and recording them.

LITTLE USE MADE OF LINE-BREEDING OR INBREEDING

The system of breeding used with college and experiment station flocks varies considerably, but only a few institutions use a definite system of line-breeding or inbreeding. Three stations report the use of inbreeding, five report a more or less definite line-breeding policy, and two report studies in cross-breeding. The remaining stations use a more or less changeable system, which may include inbreeding, line-breeding, and outcrossing over a period of years.

Seven stations definitely mention the use of selective breeding in their flocks, but it is not apparent from the reports whether this selective breeding may at times include some close matings. A very common system is to choose as good individuals as possible for rams, with some attention to the excellence of the ram's sire and dam or other close relatives. At most stations it is required that the rams be unrelated to the flock in which they are to be used.

A few stations consistently purchase rams from one flock or one family. This involves some line-breeding but rarely very much. A very few deliberately practice line-breeding to certain outstanding individual rams. This does not often go close enough to produce lambs with an inbreeding coefficient much above 16 percent. A very few others stated that when they have a ram with unusually good progeny, they do not hesitate to inbreed closely to him, using him on his daughters, sisters, and dam if these are still in the flock. Presumably such close inbreeding is not continued with the next ram unless it, too, proves to be unusually good. Hence such a breeding policy might be characterized as outbreeding with occasional spurts of close inbreeding.

Only three stations reported the use of the progeny test as a part of their program. This fact seems at first sight to indicate that there is a widespread opportunity for sheep improvement through application of the progeny test, combined with selection and breeding for the fixation of the various characters. Nearly all college and most station flocks are too small, however, to permit the simultaneous progeny testing of several rams. There are exceptions, notably the

flocks at the United States Sheep Experiment Station, Dubois, Idaho, the Texas Station Rambouillet flock, and the Montana Station flock, which are large enough for progeny testing. The Massachusetts Station reports a definite project on ways to use the progeny test. This project is being conducted in cooperation with the Bureau of Animal Industry, United States Department of Agriculture.

The most significant fact coming out of the survey is the widespread lack of data submitted on more than a single generation of breeding. Under such circumstances it is not only impossible to make anything approaching a satisfactory genetic analysis to determine the extent of progress toward purity of germ plasm for

THE *sheepman would like to produce wool of a given character and quality with greater certainty; he would like to combine this with assured production of high-quality meat; he would like to be sure of getting high-milking ewes for the sake of a good lamb crop; and he has to meet all the usual problems of diseases and weaknesses. The scientific worker finds himself faced with a great deficiency in knowledge of the way these important characters are inherited. They have not been studied partly because so much of the experimental work has been done by practical breeders who could not afford to risk unfavorable results and who were hampered by breed traditions and the pressure of their associates. The scientist should not be confined by the same restrictions, and in a forward-looking program he would be free to make his analysis of inheritance as the first step to building up a combination or synthesis of economically desirable traits.*

certain characters, but also it is difficult to form an opinion on the amount of effort the experimenters are making in this direction. It seems probable that some stations have on hand much more pertinent data than their reports indicate. Lack of time, shortage of assistance, and the unusual nature of the request may have prevented the making of full reports.

A more nearly adequate analysis of the situation at some future time may reveal that more progress has been made toward purity of germ plasm than this chapter indicates. As is shown in figure 1, many elements of individuality affecting both the judge and the sheep enter into the show record which is so widely used as a basis for selections. But the show-ring system is a purely arbitrary one. The judge frequently must make many compromises in his own mind and

there is nothing left to posterity by which future breeders may know what combination of traits made the winner. This obstacle must be removed before the science of genetics can play any significant role in the further improvement of sheep. In fairness to both the show-ring system and the geneticist who finds the show record inadequate, it must be admitted that some of these traits may never be reducible to mathematical expression.

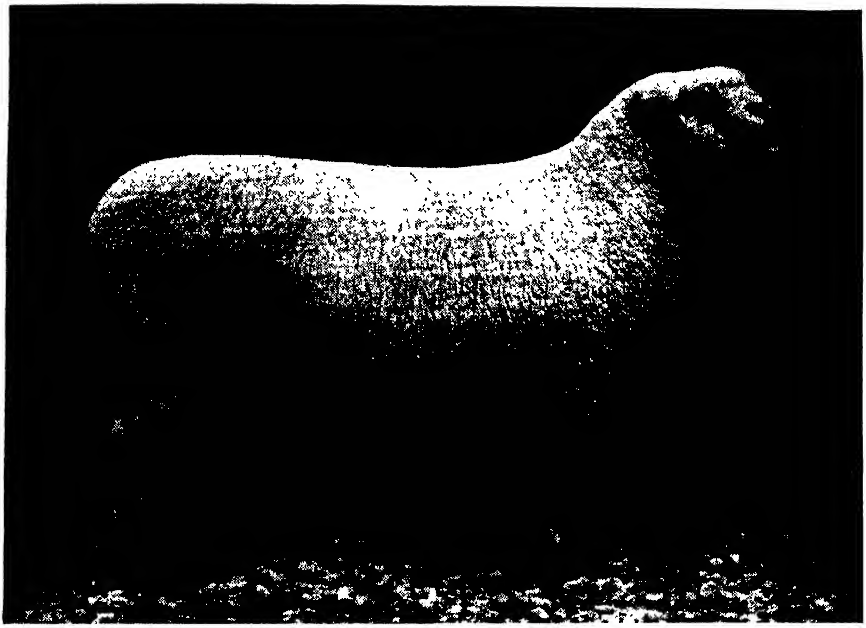


FIGURE 1.—Southdown ram, bred in England, champion at the 1930 International Live Stock Exposition. A half brother out of his dam was reserve champion at the English Royal. His sire was first prize yearling ram and reserve champion at the English Royal, and sired, in addition to this American champion, a champion ram at the English Royal and many winners of lesser prizes in British shows.

The sheep-breeding projects now being carried on at the various agricultural experiment stations are shown in the following tabulation:

Sheep-breeding and some related projects at the agricultural experiment stations and the United States Department of Agriculture

Florida: Columbia sheep performance investigations.
Georgia: Sheep breeding for Georgia conditions.
Idaho: Black spotting in Rambouillets; turned-in eyelids (entropion) in lambs—a study of the inheritance; overshot jaw (prognathism) and undershot jaw (brachygnathism) in sheep—an inheritance study.
Kentucky: The introduction of purebred sheep; to establish a flock of purebred sheep consisting of four breeds—Cheviot, Hampshire, Shropshire, and Southdown.
Maryland: Breeding of new flocks suitable for early-lamb production.
Massachusetts: Cooperative sheep project with the Bureau of Animal Industry—a record-of-performance study; physiology of reproduction—incidental studies of the scrotal reactions to temperature relative to the testes and anterior pituitary hormones.
Michigan: The improvement of wool production in Rambouillet and other breeds of sheep.
Minnesota: A study of the embryological development of the sheep.
Mississippi: A study of the inheritance of the factor for time of weaning with sheep; a study to determine the relative value of Corriedale, Hampshire, and Southdown breeding in the sheep-production program of Mississippi.

Montana: Inheritance of size, form, and productive capacity of range ewes; heredity as a factor in the determination of twinning in Rambouillet sheep.
Nebraska: Sheep breeding.
Nevada: Methods of producing more and better lambs in Nevada range flocks.
New Hampshire: Fertility and milk production of sheep.
North Carolina: A study of the changes in meat and wool characteristics resulting from the use of purebred rams on native ewes.
North Dakota: A study of the inheritability of wool by market grades; a study of ewe-lamb breeding.
Ohio: Straight breeding *versus* cross-breeding of Merino ewes.
Oklahoma: Effect of nutrition on the physiology of reproduction of sheep; correlation studies of wool and the behavior of various factors in inheritance.
Pennsylvania: Hothouse lamb production.
South Carolina: A genetic study of the inheritance of the early-lambing character.
South Dakota: Breeding of Karakul sheep; crosses with other breeds to develop quality of Karakul lamb fur; tailless sheep; combining the unit characters of the fat-rumped Siberian sheep, which is tailless, with those of the Rambouillet.
Texas: Inheritance of the polled characters in fine-wool sheep; cytological and hybridization studies with sheep and goats; a study of the inheritance of skin folds on Rambouillet sheep.
West Virginia: Breed as a factor in sheep production and quality of products produced.
Wyoming: Breed studies with Hampshire sheep; breeding western ewes for wool and lamb production; Australian Merino wool—(1) the effect of Wyoming climate on the wool of Australian Merino rams, (2) the prepotency of Australian Merino wool in crosses of Australian Merino rams on Rambouillet ewes.

Sheep-breeding projects of the Bureau of Animal Industry, United States Department of Agriculture

Sheep-breeding investigations of performance in lamb and wool production with Merinos, Rambouillets, Corriedales, and Columbias on the range, and with Hampshires, Shropshires, Southdowns, Corriedales, and Dorsets under farm conditions.
Sheep-breeding investigations of performance in fur production with Karakuls.
The development of breeds and strains of sheep suitable to southwestern ranges and to the economic requirements of sheepmen.

Breeding projects in which sheep take a prominent part

California (Davis): Vitamin A in relation to reproduction in sheep.
Iowa: The comparative amount and kind of inbreeding and other breeding practices which have been used in producing the pure breeds of livestock and uses of these findings in further improvement of breeding stock.
Missouri: Physiology of reproduction in farm animals.

TEN YEARS' RECORDS IN TEXAS

The Texas Agricultural Experiment Station returned more data than any other in the United States. It is apparent that during the last 10 years very complete data on weights, type, and wool characters have been systematically recorded in such a manner that daughter-dam comparisons for the offspring of different sires are easily made in the Texas Station's Rambouillet flock. Data on wool characters were reported for both ram and ewe offspring sired by six different rams used in the flock since 1924. In one case records on 63 daughters by one ram were available, although only 15 were from dams having yearling records on clean wool, shrinkage, and staple length, and 22 from dams having a record on fineness of fiber.

Two of the six rams were outstanding in that they sired daughters averaging longer staple, heavier clean-wool fleeces, and lighter shrinking fleeces of finer wool than their dams. One of these rams was bred by the experiment station and the other was purchased as a lamb from a leading Rambouillet breeder. Since the period of their use—

1922–27 and 1924–27—the endeavor to locate superior sires has been continued. During the past several years increased attention has been given to the discovery of such valuable sires within the station flock. This is a desirable procedure, because when one is located there will be available a set of records that may make the identification or development of the next one an easier task.

The Texas Station also reports an interesting case of inheritance of the polled character in Rambouillet sheep. Eight rams of polled breeding have been tested and two have been found to be homozygous for the polled character.

RECORDS OF PRIVATE BREEDERS

The incompleteness of the data received from most of the experiment stations made it impractical to go ahead with the original plan of sending similar questionnaires to those private breeders reported by State workers as having flocks wherein superior germ plasm may exist. The request for names brought in a total of only 54, representing all breeds of sheep. Many of the State workers explained, however, that there might be other flocks in the State just as valuable but unknown to them. There was a distinct hesitancy to discriminate by naming only the flocks they happened to know. This situation is due largely to the fact that no method has ever been set up in any State for measuring merit in all flocks of sheep. The nearest approach to anything of the kind is the few attempts by breeders to record the weight and grade of fleece produced by their best sheep, not by the flock as a whole.

At the present time there is an exceedingly wide gap between the system of records actually kept by breeders and the system that would be required to prove progress and indicate the existence of superior germ plasm for the various characters in sheep. There cannot be any real genetic evaluation of the flocks reputed to be superior until this gap has been at least partly bridged. To what extent this can be done remains to be seen, but it is a complex problem for the experimenter, the breed associations, and the breeders to solve.

TWO KINDS OF SUPERIORITY

Probably in no class of domestic livestock are there so many variations of economic importance as there are in sheep. Not only are there two main groups represented by the mutton and wool breeds, respectively, but among the wool breeds there is a great variety of characters, each of which plays an economically significant role. In the composite of all these characters there are some antagonisms, and seldom or never would the extreme expression of all characters be seen in one individual. For instance, the long fiber of the Lincoln, the fineness and crimp of fiber of the Merino, the skin folds of the Rambouillet, and the extreme mutton conformation of the Southdown do not occur together.

In addition to the wool and conformation characters of the two contrasting types of sheep, the wool and the mutton types, a third group of inherent factors affecting the production of milk and butterfat are important constituents of superior germ plasm. This group of factors has received almost no attention from the geneticist, but indirectly it probably receives considerable attention from sheep breeders. Success in raising superior lambs is so dependent on the milk production of the ewe that any consideration of superior inheri-

FIGURE 2

Hampshire ewe no. 56319, on the left, and five successive generations of her female descendants. They were 13, 11, 9, 6, 3 years and 1 year old, respectively, on the day these individual pictures were taken at Beltsville, Md. During her lifetime, in 11 lambings this ewe produced 15 lambs and raised 13 of them.

tance should include milk as well as wool or meat. Ritzman of the New Hampshire Agricultural Experiment Station has shown that both yield and fat content of milk vary widely, and it is safe to assume that at least part of the variation is due to heredity. By comparing the growth of lambs from poor milkers with that of lambs from high-milking ewes, he observed a difference of 79 percent in favor of the latter up to 16 weeks of age.

The Need for More Knowledge of Inheritance in Sheep

SHEEP breeding has always been an important part of animal husbandry but has not yet been practiced to any significant extent as a means of determining the exact hereditary constitution of the species. Although considerable experimental breeding work has been done and many observations having some genetic significance have been made, in only a relatively few cases do these studies concern the characters of economic importance in sheep. Furthermore, so many uncontrolled factors frequently affect the expression of the characters that exact interpretation of their genetic basis is impossible or at best can be made in general terms only.

The various breeds of sheep have been developed by practical breeders to meet their varied needs, and there is so much variation in these breeds that it is easily possible to change the characteristics of a given strain by selection alone. This situation is not an obstacle to further research because the breeder or producer is not the one who is going to do the genetic research. Recognition of the fact that the breeder cannot afford to engage in scientific studies with the chance that some of the results will be unfavorable does not mean that the scientific investigator has to be limited in the same way. One trouble in the past has been that many of the experimenters were practical breeders, and were somewhat hampered by their own breed traditions and the pressure of their associates.

FIGURE 2

The line is noted for its hardihood and longevity. Considering that these ewes did not produce lambs before they were 2 years old and that the average usefulness of a Hampshire ewe is between three and four lambings, it is doubtful if such a record could often be achieved, if attempted.

It is clear that the breeder and the geneticist are concerned with the same problems, but they approach them in different ways. One wants to build up combinations of traits that will give him the best sheep for his particular purpose; the other wants to find out how the various traits are inherited. Obviously, the latter is the sound way to approach the problem from the scientific standpoint, but the approach has usually been the other way around for all of our domestic animals.

It is not the intention here to discuss all the experiments that have been conducted on inheritance in sheep. They cover a fairly wide range, including color, fleece characters, ear length and form, horn growth, tail length and form, number of mammae, fecundity, anatomical abnormalities, mutton conformation, and hybridization studies. A résumé of the work up to 1925 has been made by Roberts and Crew, and a list of all the important articles up to 1929 was published by the Imperial Bureau of Animal Genetics, Edinburgh, Scotland, in 1931. It seems necessary to discuss here only the characters of economic importance because they are the ones with which the present survey was primarily concerned.

One of the few experiments on measurements of mutton form and its genetic basis was carried on at the New Hampshire Agricultural Experiment Station by Ritzman. The genetic aspect of the work involved crosses on a small scale between Rambouillet and Southdown breeds. The first-generation animals were usually intermediate in mutton conformation between the two parents. In the second generation after the cross there was strong evidence of segregation. The evidence obtained indicates clearly that multiple factors are concerned and that a large second-generation population must be raised before the parental types are recovered.

In a similar study in England involving Merino and Shropshire sheep, Mackenzie and Marshall also found a complex genetic situation in the inheritance of conformation as related to mutton production. It is evident from their results that there was considerable variation in the inheritance carried by the parental stocks, since the characteristics of the first-generation hybrids were somewhat variable although, on the average, intermediate between those of the parents. The second-generation hybrids showed slightly more variability but

not enough segregation to give concrete evidence on the nature of the inheritance involved. The results show that the hereditary differences between the fine-wool and the mutton breeds used are many, and a satisfactory analysis of the situation will require not only large numbers of breeding animals but animals of reasonably homozygous composition to start with.

THE SITUATION IN THE MUTTON BREEDS

Just as the consumer eats large quantities of meat from dairy breeds of cattle, so also will he eat large quantities of lamb and mutton produced by the wool breeds of sheep, so long as wool production occupies a place of importance in American agriculture. This has a relation to superior germ plasm for meat production in the sense that economic pressure makes it desirable to produce both milk and meat or wool and meat in the same herd or flock. In the future this pressure may increase with changing economic conditions, but genetically the problem is one of combining important economic characters. However, there is the possibility that combinations in relatively pure genetic form may already have been made by breeders, and if so their identification is a matter of great importance.

The principal mutton breeds of sheep in the United States are the Hampshire, Shropshire, Oxford, and Southdown. The Lincoln, Cotswold, Corriedale, Dorset, Cheviot, Romney Marsh, Leicester, and Suffolk are numerically of much less importance. Since these breeds include both the medium- and long-wool classes, there is considerable variation in the combinations of heredity involved. In actual practice both wool and mutton characters must be dealt with simultaneously, but for purposes of genetic discussion each is treated separately.

The problem of superior germ plasm relative to meat production among these breeds is similar to that in swine and beef cattle in that it concerns fertility, general vigor, rapidity of gain, economy of feed utilization, and conformation. Also, the difficulty of measuring genetic variations in these characters is just as acute among sheep as among the other classes of animals, and the comments made in the sections of this Yearbook which deal with these other classes apply here also. Broad, well-muscled backs and loins, plump legs, and uniformity of finish, combined with high fertility, constitute much of the mutton ideal. This condition has been approached in many of the mutton breeds of today, but the great amount of intrabreed variation and the rapid rate at which animals degenerate in the hands of unskilled breeders are conclusive evidence of the lack of genetic purity for the economic traits of form and function.

The question, in popular language is, where do we go from here with the specialized mutton sheep?

The stage is hardly set for the curtain to rise; the instruments have to be tuned to a standard before the overture can begin. In other words, the breeder does not yet have the information necessary to identify the superior germ plasm in his flock, and the experimenter must find that information. While variations in body proportions and size can be measured with available instruments, the real genetic significance of these is not yet clear. There is urgent need for research on this problem to ascertain what data can be effectively applied in a breeding program.

The work dealing with improvement in mutton qualities carried on in the Department has shown the futility of collecting data based entirely on human judgment. This is particularly true when several different points of conformation are being considered at one time. Committee scoring of type, condition, back, rump, and leg, and the use of these scores in progeny testing and selective breeding, have served only to maintain the average grade for each characteristic at a certain level. What actual measurements might replace such judging and be more effective can only be guessed at present; but by using as a starting point work already done, such as that on physical measurements and inheritance of size and conformation carried on at the New Hampshire and Wyoming Stations, the experimenter should be able to make some progress in determining what kind of data can be obtained that will be reliable and useful.

THE SITUATION IN THE WOOL BREEDS

A strict separation of breeds of sheep into two arbitrary classes, wool breeds and mutton breeds, is not possible because both meat and wool are used in the case of every domestic sheep of importance in this country. The only exceptions among domestic sheep are the woolless breeds known as Blackhead Persian and Barbados. It is usual to divide the various breeds into three classes based on the length and fineness of the wool fibers. Thus, we have the fine-wool, the medium-wool, and the long-wool classes. Such a classification includes the breeds kept primarily for mutton as well as those raised for wool. When the term "wool breed" is used, it usually implies one of the breeds kept primarily for fine wool, such as the Rambouillet and Merino, while the term "mutton breed" designates a breed that excels in mutton quality rather than wool. For example, the Hampshire, Southdown, Shropshire, and Oxford breeds would be included in the latter class, yet all produce both mutton and wool, and the separation into two groups is an arbitrary one. The third, or long-wool group, includes such breeds as Lincoln, Leicester, Cotswold, and Romney Marsh, and these are also of the mutton type.

It is useful to know the kind of wool produced by different animals, and a list of the more common breeds, showing the wool characteristic of each, is given in table 2.

Some breeds may be said to occupy an intermediate position similar to that occupied by dual-purpose cattle bred to produce good-quality beef plus an amount of milk somewhat intermediate in quantity between that of the specialized dairy and the beef breeds. The statements made in the section on dual-purpose cattle on the difficulty of handling two such divergent characters apply broadly to many breeds of sheep. The fact that breeders give more attention to wool or to mutton makes for genetic instability for the two characteristics. The result, genetically, is an alternate building up and tearing down of heterozygous combinations of hereditary material.

The breeder benefits from the flexibility or heterozygous nature of his breeding stock in two ways: (1) He is able to change the characteristics of the stock in a comparatively short time and can thus follow, with some lag, changes in market demand for wool and mutton. (2) Probably in many cases the stock has greater vigor because of the heterozygous combinations that result from the system of breeding employed. Of course some breeders even go so

far as to cross-breed deliberately in order to maintain greater vigor and change the characteristics of their flocks rapidly. This is no doubt the quickest way to get these results if the right strains are available for crossing; but with the present knowledge of inheritance relative to both wool and mutton, the strains that will "nick" advantageously can be located only by the method of trial and error. Such cross-breeding may be the means of bringing together desirable heredity that can be concentrated into true-breeding superior strains. For example, in 8 years' comparison with ewes of four breeds, the Columbia breed, developed in the Department of Agriculture from a cross involving Rambouillet ewes and Lincoln rams, produced more wool and the lambs reached a greater weight at weaning time than was the case with the other four breeds.

TABLE 2.—*A list of wool classifications, grouped according to fineness of wool, of the more common breeds of sheep, together with a description of the kind of wool each produces and some of the uses to which it can be put in the manufacture of cloth*

Breed	American grades of wool	Numerical grades of wool	Uses
Merino and Rambouillet.	Fine and half blood	58's and finer	Used in making fine dress goods and flannel.
Southdown	Half and three-eighths blood combing and clothing (chiefly three-eighths blood clothing).	58's and 60's in the half blood; 56's in the three-eighths blood.	The half-blood wool is used mostly for fine dress goods, the three-eighths blood for the manufacture of cloth such as serges, twills, whipcords, herringbones, and other materials used for coatings and suitings.
Corriedale, Dorset, Hampshire, Shropshire, Suffolk.	Mainly three-eighths blood combing or clothing and some quarter blood (both fine and coarse classes of medium wool).	56's in the three-eighths blood; 48's and 50's in the quarter blood.	Used mostly in the manufacture of suitings.
Cheviot	Usually quarter blood combing (that is, the coarse side of medium wool).	48's and 50's	Do.
Oxford	Quarter blood and low quarter blood combing (that is, the coarse side of medium and the fine side of coarse wool).	46's and 48's	The quarter blood is used in the manufacture of suitings, and the low quarter blood is used in making such materials as heavy overcoats, blankets, and carpets.
Cotswold, Leicester, Lincoln, Romney Marsh.	Low quarter blood, common and braid.	Chiefly 46's, 44's, 40's, and 36's; a small percentage produce finer than 46's.	Used mostly in the manufacture of heavy overcoatings, blankets, and carpets.

The production of wool was the primary purpose of the American sheep industry until about the last decade of the nineteenth century. Since then the market demand for lamb and mutton has developed so that all commercial sheep producers are striving to include excellent mutton qualities in the wool type as well as in the mutton type. At the same time the yield of wool per sheep has also increased, until now the average annual fleece weight in the United States is about 8 pounds, whereas a century ago it was only about 2 pounds.

Yardsticks Needed for Wool

There is a widespread opinion that the measurement of the wool production of a sheep is a simple matter and that wool characters can be easily and quickly determined in exact mathematical units.

This is quite contrary to the facts. Although the technique of measuring variations in wool characters is far more advanced than it is for mutton, much still remains to be done both in the refinement of methods and in their adaptation to practical use by experimenters and sheep breeders. There is no standardized procedure for accurately measuring length of fiber, and as yet there is no accurate measure of crimp sufficiently rapid for practical use even by research

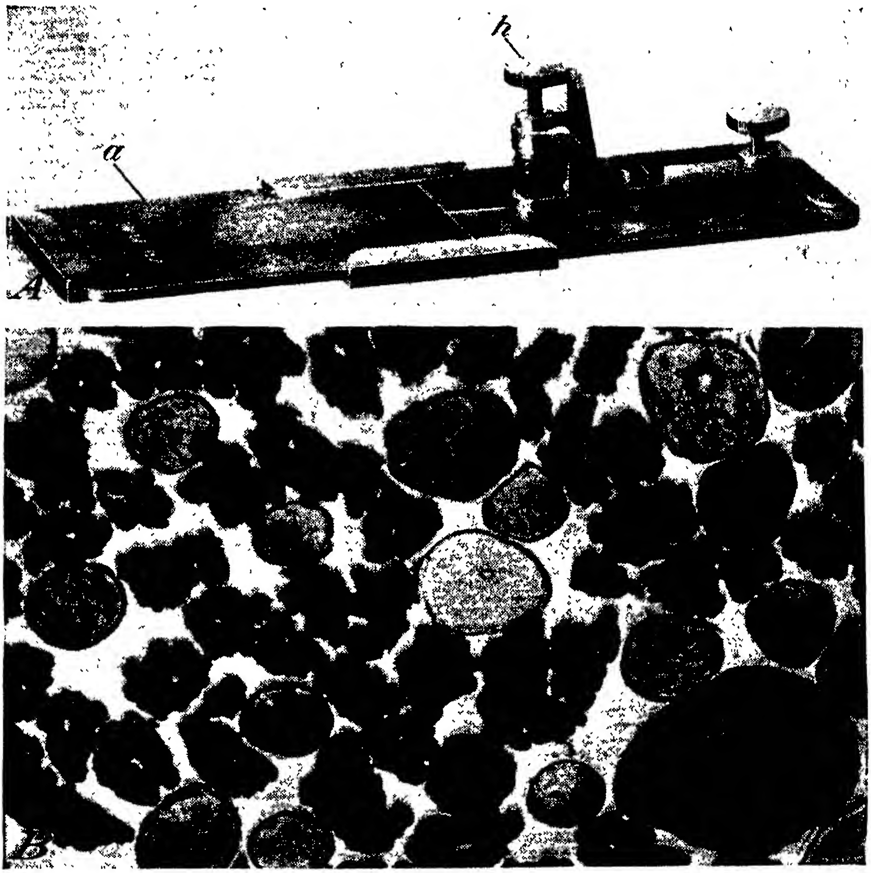


FIGURE 3.—*A*, Device for holding fibers for cutting extremely thin cross sections of opaque fibers for making detailed study of structure, or for fineness studies. Microscopic sections can be prepared in 15 minutes as compared with 2 days by old methods. Fibers are pushed into the slot by a tongue on the movable slide *a*. The plunger *h* then pushes the fibers through the slot to the extent desired, and a sharp safety-razor blade is used to make a clean slice. The plunger is alined with the slot to a ten-thousandth of an inch. *B*, A photomicrograph of a portion of a thread from a piece of men's suiting appearing to be all wool, but found to be a mixture of wool and delustered rayon.

workers. Nineteen of the twenty-four experiment stations reporting data make records of fleece weight, but only five of these obtain the weight of clean wool. Also, only about one-third of the stations record length of staple, fineness, and uniformity of fleece.

Within recent years much progress has been made toward perfecting methods and devices for measuring important characteristics of fleeces and physical properties of wool. At present, some are of practical use only for the experimenter, but others have been so simplified that they are available to flock owners who wish to study

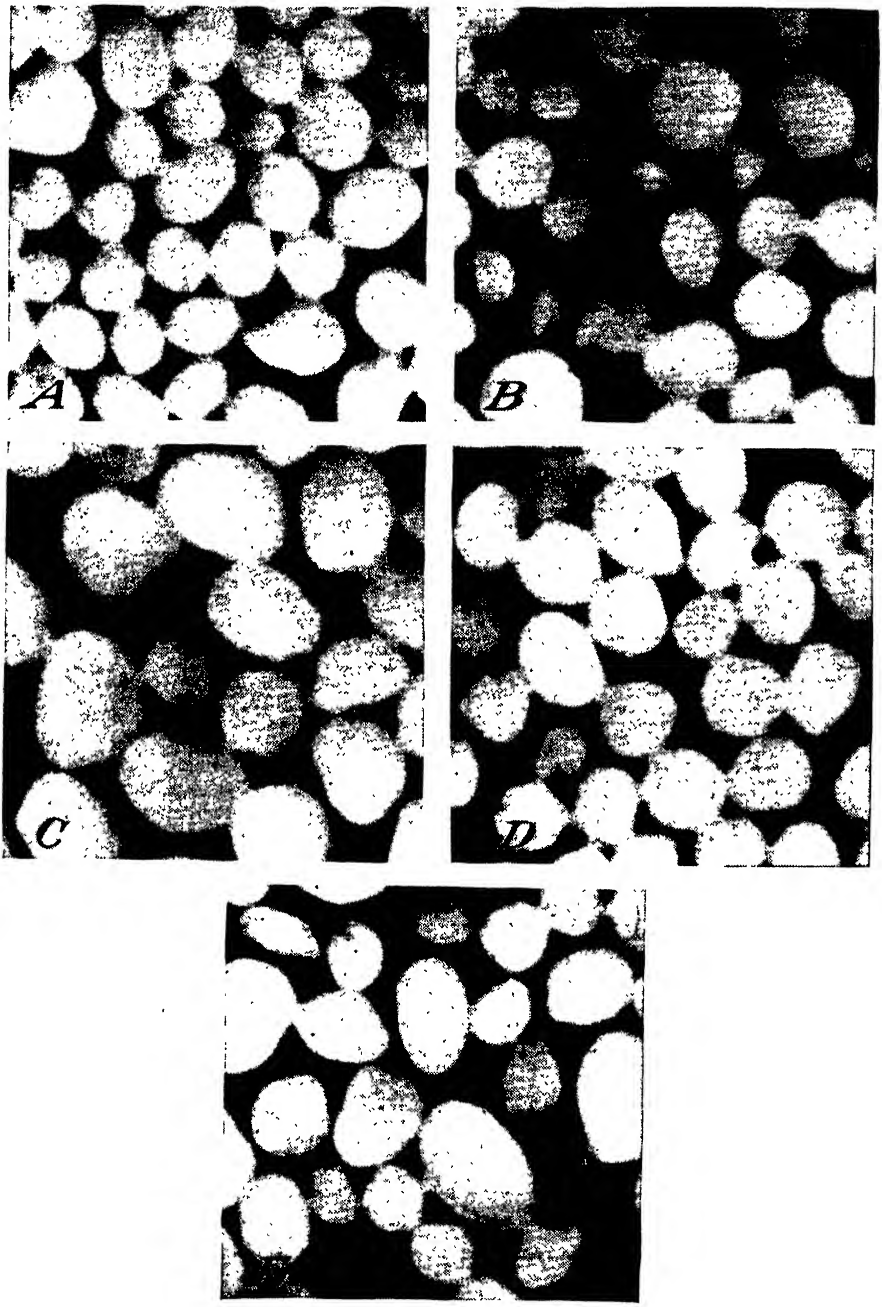


FIGURE 4.—Photomicrographs of a cross section of wool: *A*, Very fine and reasonably uniform wool from a grand champion fleece grown on a grade Rambouillet ewe; *B*, very fine wool from a first-prize registered Rambouillet ewe fleece; *C*, very uniform but coarse wool from a registered Rambouillet ram fleece; *D*, very uniform wool from the fleece of a registered Merino ewe; *E*, wool greatly lacking in uniformity from a first-prize fleece grown on a purebred Merino ewe. All × 500.

the fleeces of their breeding animals with more precision than can be done by touch or with the unaided eye. Among the latter is an instrument, perfected in the Department's animal fiber research laboratory, for making cross sections of fibers arranged as they occur naturally in the fleece (fig. 3, *A*). Photographic projections, such as

FIGURE 5.—Karakul lambskin showing characteristic tightness of curl and luster.

shown in figure 4, are then made of these fibers showing their relative and actual size and shape, and their internal and surface structure as well, when the device illustrated in figure 3, *A*, is used. Their distribution as they grew is also clearly shown.

Studies of representative fleeces made with this device have revealed some details that the unaided eye is unable to judge accurately.

Density, crimp, luster, and other factors influence eye judgment, and a predominance of fibers of one fineness seems to attract the eye from fibers of widely different fineness and therefore causes the observer to misjudge the average fineness of the sample. By using the device it has been found that first-prize fleeces of the wool breeds frequently have much greater uniformity with respect to size of fiber than grand-champion and reserve grand-champion fleeces of the same breed at the same show.

It appears that the prevalent method of judging fleeces at shows is a relatively superficial one when it comes to the essential details fundamental to real differences in quality. Judging fleeces by touch and with the unaided eye does not detect sufficient detail for the result to be useful in breeding for fleeces of greater uniformity. Much lack of progress in breeding with this objective during the past decade is due to the fact that the measures employed are not exact enough to record essential variations in the several characters involved. For instance, in fur-breeding studies with Karakul sheep, progress has been retarded by the lack of physical measures of such important characters as curl and luster. A purebred Karakul lambskin is shown in figure 5.

Physical Properties Versus Hereditary Basis

There are few conclusive data to show the mode of inheritance of the important characteristics of wool. However, there is a considerable amount of literature dealing with observations made on some aspects of sheep breeding or wool inheritance. For instance, in The Bibliography on the Biology of the Fleece, by Crew, 434 citations are given, although an examination of the titles shows that only about one-third deal with breeding.

Many of the studies reported concern characters other than length, fineness, crimp, percentage of grease, etc. Much effort seems to have been expended on statistical analysis of the interrelationships existing between the physical properties of wool and various other sheep characters. For instance, density, character, and weight of fleece, fineness of fiber, length of staple, percentage of grease, age of sheep, body weight, and mutton type have been studied by many workers who have determined the degrees of association between such characters.

This is the sort of situation that comes from the accumulation of data and their subsequent analysis to discover the relations existing between the various characters involved. No matter how exact the results may be, however, they deal with only one generation, and this is their weakness from the breeding standpoint. Although such a study confined to one generation is necessary and desirable from certain standpoints, it will never contribute anything to our knowledge of genetics, and what we now need to do is to make a study of each variable as it appears in successive generations. Only in this way can we determine how the various wool characters are affected by heredity.

One must not be misled into thinking that the mode of inheritance of the various characters will be quickly and easily determined. On the contrary, this will probably be a slow and tedious process. The small amount of work that has been done to date on the inheritance of wool characters shows clearly that multiple factors are concerned,

and that there is a widespread lack of dominance among the various genes involved. A careful and reasonably complete genetic analysis of each character would be valuable to both the geneticist and the breeder. In making this analysis, one of the first things necessary will be the development of strains that are to a large extent true in their breeding for certain characters. This is a job for the experimenter rather than the practical breeder because the process is certain to be an expensive one.

But while the experimenter is doing this, perhaps contributions of some value can be made by analyzing data on a generation basis rather than an annual basis. Such a change would make possible the construction of pedigrees that would give the important characteristics of each ancestor. Thus the various traits could be followed from one generation to the next. Only in a relatively few cases is this possible at the present time.

There is a feeling, however, that unless it can be shown that keeping individual records for wool would bring enough increased profits to balance the extra cost, it will never meet with favor among breeders. This should stimulate the research worker to develop a method that will make the breeder's part of the work easier and more practicable. In the meantime, care should be exercised to keep experimental procedures within proper bounds and not to mislead the wool grower into changing his system for one that may bring him decreased returns. He depends on his profits for a living, and up to this time his own methods have served reasonably well for this purpose.

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Appendix

Some Workers Identified with Sheep Improvement at State and Federal Experiment Stations

Alaska, College: G. W. Gasser.
Arizona, Tucson: E. B. Stanley, E. L. Scott.
Arkansas: W. R. Horlacher.
California, Berkeley: R. F. Miller, J. F. Wilson, P. W. Gregory.
Colorado, Fort Collins: G. E. Morton.
Connecticut, Storrs: H. L. Garrigus.
Florida, Gainesville: A. L. Shealy, L. O. Gratz.
Georgia, Griffin: F. R. Edwards, W. S. Rice, Z. A. Massey.
Idaho, Moscow: C. W. Hickman, J. E. Nordby.
Illinois, Urbana: W. G. Kammlade, E. Roberts.
Indiana, Lafayette: Claude Harper, E. E. Van Lone.
Iowa, Ames: J. L. Lush, C. C. Culbertson, J. H. Bywaters.
Kansas, Manhattan: R. F. Cox, H. L. Ibsen.
Kentucky, Lexington: E. S. Good, L. J. Horlacher.
Louisiana, Baton Rouge: M. G. Snell.
Maryland, College Park: B. E. Carmichael, K. G. Acker.
Massachusetts, Amherst: V. A. Rice, C. H. Parsons, R. W. Phillips, R. C. Foley.
Michigan, East Lansing: G. A. Brown, V. A. Freeman, H. R. Hunt.
Minnesota, St. Paul: W. C. Coffey, P. A. Anderson, L. M. Winters, O. M. Kiser.
Mississippi, State College: E. W. Sheets, H. H. Leveck.
Missouri, Columbia: F. F. McKenzie.
Montana, Bozeman: D. W. Chittenden, Frank Barnum.
Nebraska, Lincoln: M. A. Alexander.
Nevada, Reno: F. W. Wilson, C. E. Fleming.
New Hampshire, Durham: E. G. Ritzman, L. V. Tirrell, H. H. Latimer.
New Mexico, State College: J. H. Knox, K. W. Parker.
New York, Ithaca: J. P. Willman.
North Carolina, Raleigh: E. H. Hostetler, J. E. Foster, G. L. Newton, H. H. Bolling.
North Dakota, Fargo: E. J. Thompson, A. S. Swenson.
Ohio, Wooster: D. S. Bell, M. A. Bachtell, C. S. Plumb.
Oklahoma, Stillwater: W. L. Blizzard, O. S. Willham.
Oregon, Corvallis: O. M. Nelson.
Pennsylvania, State College: W. L. Henning, P. C. MacKenzie, J. F. Shigley, P. T. Zeigler.
South Carolina, Clemson College: L. V. Starkey, E. G. Godbey.
South Dakota, Brookings: J. W. Wilson, T. R. H. Wright.
Tennessee, Knoxville: Moses Jacob, C. C. Flanery.
Texas, College Station: J. M. Jones, B. L. Warwick, A. K. Mackey, W. H. Dameron.
Utah, Logan: E. J. Maynard, S. P. Davis, R. O. Berry, A. C. Esplin.
Washington, Pullman: H. Hackedorn.
West Virginia, Morgantown: E. A. Livesay, C. V. Wilson, B. F. Creech.
Wisconsin, Madison: G. C. Humphrey, A. E. Darlow, L. J. Cole.
Wyoming, Laramie: J. A. Hill, F. S. Hultz, R. H. Burns, S. S. Wheeler, J. A. Gorman.
United States Department of Agriculture, Bureau of Animal Industry, Washington, D. C.: D. A. Spencer, J. I. Hardy, C. G. Potts.
Field stations:
Dubois, Idaho: Stanley L. Smith, John A. Stoehr.
Middlebury, Vt.: Earl B. Krantz.
Beltsville, Md.: M. B. Potts, V. L. Simmons, J. O. Grandstaff.
United States Department of the Interior, Bureau of Indian Affairs, Fort Wingate, N. Mex.: J. M. Cooper, Herbert King, Jr.

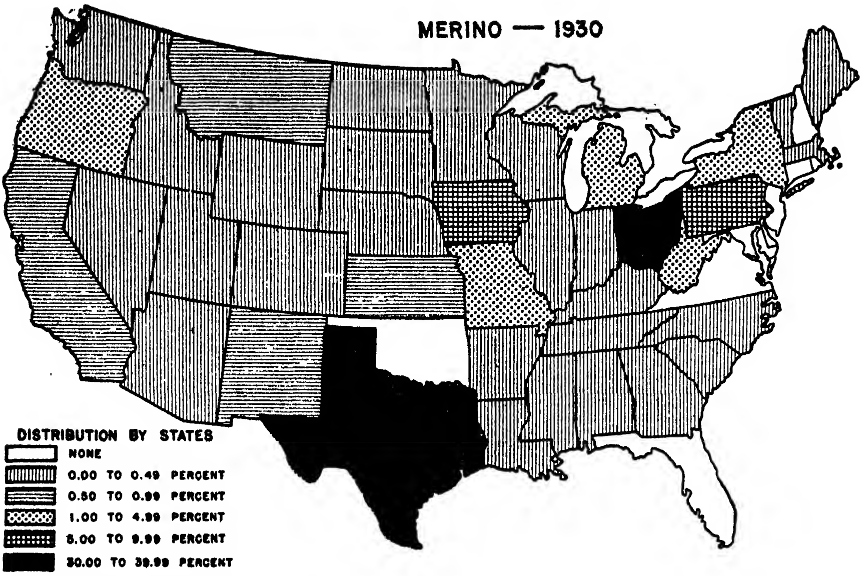


FIGURE 6.—Distribution of purebred, registered Merino sheep by States, census of 1930. Ohio is the banner Merino State, having 39.61 percent of the purebred, registered sheep of this breed. Texas is second with 30.78 percent of the Merinos. About 25 percent of them are in the seven States—Iowa, Pennsylvania, Michigan, Missouri, Oregon, New York, and West Virginia—and the remaining 5 percent are sparsely scattered over the other 39 States.

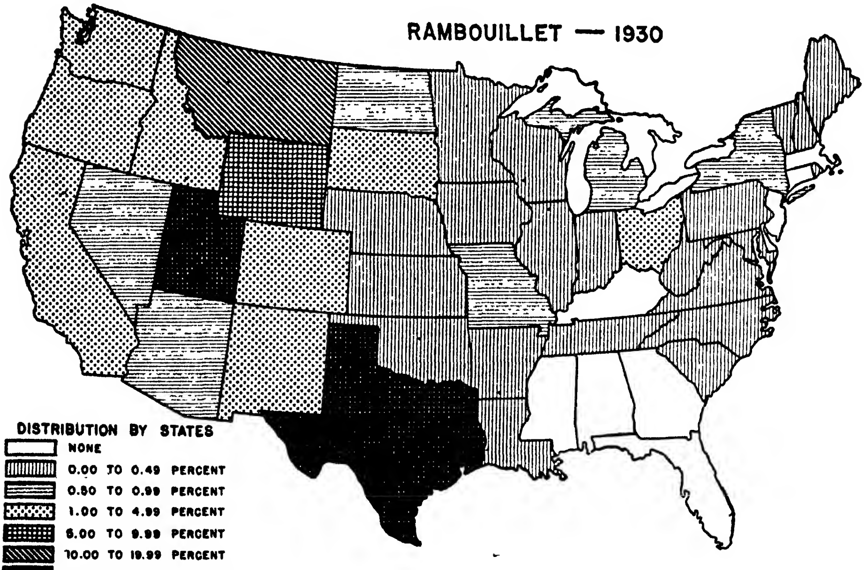


FIGURE 7.—Distribution of purebred, registered Rambouillet sheep by States, census of 1930. Texas leads in the production of Rambouillet sheep, having 28 percent of the total, and Utah with 27 percent nearly ties with Texas as the breeding ground for this western fine-wool breed. Montana has 10 percent and Wyoming 5 percent of the Rambouillets. About 92 percent of the sheep of this breed are in the 11 far Western States and Texas. Ohio with 2.62 percent is the only State in the eastern half of this country that has more than a fraction of 1 percent of the Rambouillets.

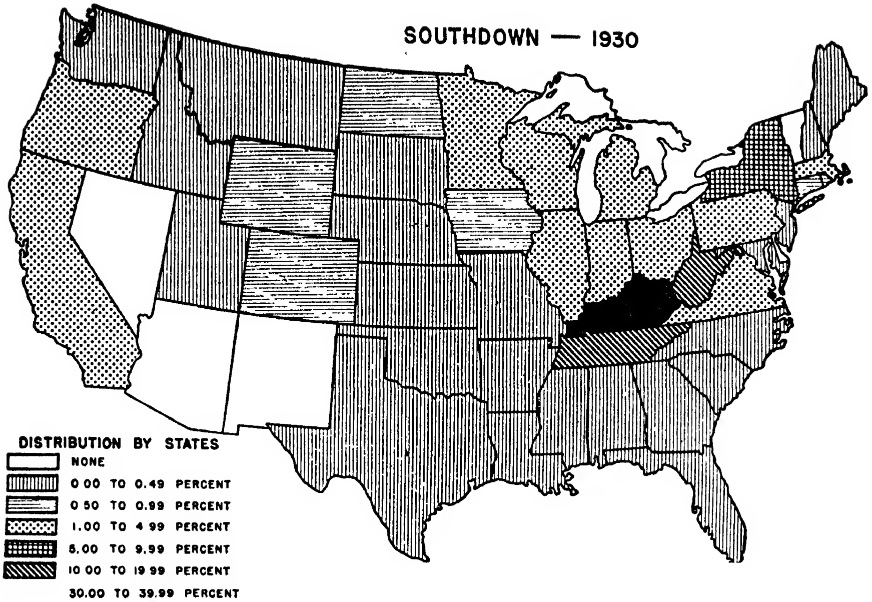


FIGURE 8.—Distribution of registered, purebred Southdown sheep by States, census of 1930. Kentucky leads in Southdowns with 39.20 percent. Tennessee follows with 15.18 and West Virginia with 11.57 percent. These three States, therefore, have nearly two-thirds of all the Southdowns.

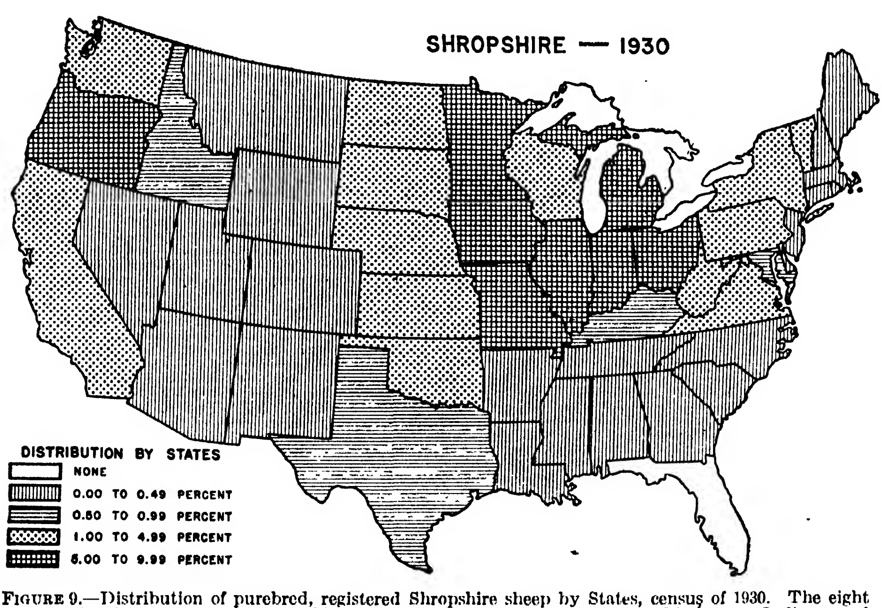


FIGURE 9.—Distribution of purebred, registered Shropshire sheep by States, census of 1930. The eight States that lead in Shropshires are Michigan, Missouri, Iowa, Ohio, Oregon, Minnesota, Indiana, and Illinois in the order named. These eight States have 64 percent of all the Shropshires. About three-quarters of all the Shropshires are in the northeast quarter of the United States, lying north of the southern boundaries of Missouri, Kentucky, and Virginia and east of the western boundaries of Minnesota, Iowa, and Missouri.

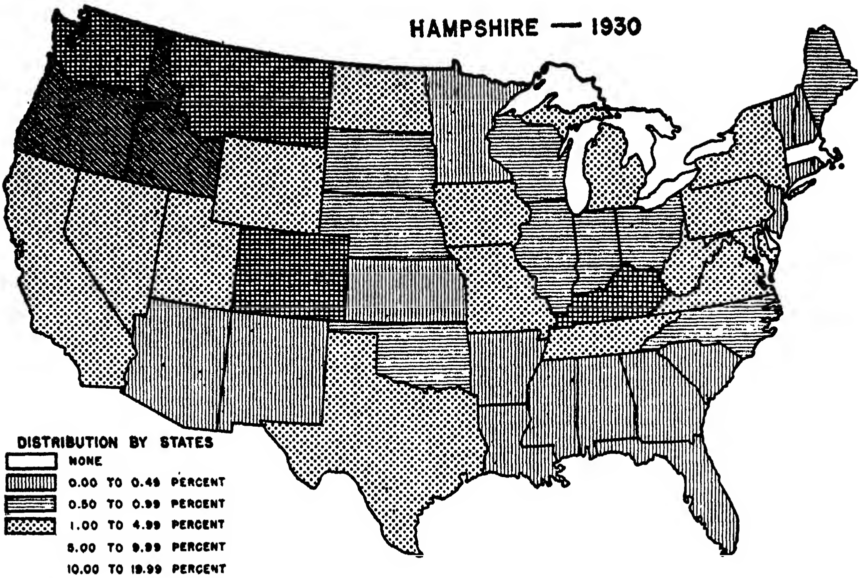


FIGURE 10.—Distribution of purebred, registered Hampshire sheep by States, census of 1930. The States that lead in the production of Hampshire sheep are Idaho with 19.59 percent, Oregon 14.21, Montana 7.51, Colorado 6.25, Washington 5.53, Kentucky 5.13, California 4.68, and Utah 4.47 percent. Two-thirds of the Hampshires are in the 11 far Western States and Texas

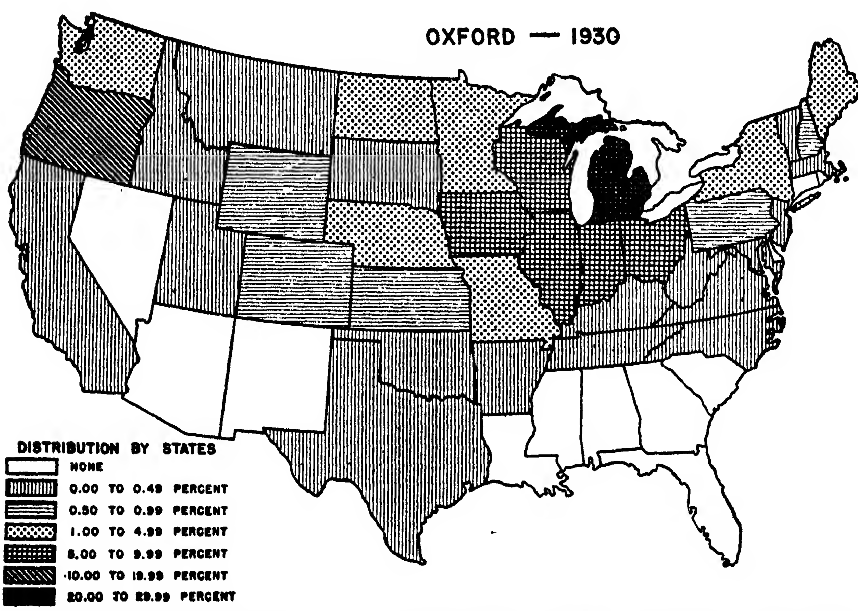
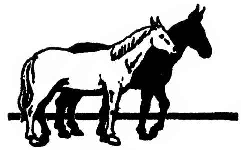


FIGURE 11.—Distribution of registered, purebred Oxford sheep by States, census of 1930. Michigan leads in Oxford sheep with 21.32 percent. Oregon is second with 11.69 percent, followed by Illinois 9.22, Iowa 7.52, Wisconsin 6.47, Indiana 6.06, and Ohio 5.10. The five East North Central States and Iowa have more than half of all the Oxfords.

Improving Horses and Mules



By J. O. Williams, Senior Animal Husbandman, and William Jackson, Associate Animal Husbandman, Bureau of Animal Industry

THE breeding of horses is an art that goes far back in history. No animal, with the possible exception of the dog, has had so much affection and respect from man as the horse, and it is safe to say that few possessions are more cherished than a fine horse. The desire to breed better animals has been correspondingly strong, and much lore about horse breeding has developed during many generations. For reasons that will be made plain in this brief survey, however, the new science of genetics has as yet achieved little in this field. No attempt is made here to record the history of horse breeding, but only to sum up certain aspects of the situation from the scientist's viewpoint.

In order to show what progress has been made in the fixation of inheritance for various characters in horses, the cooperation of each State agricultural experiment station was asked to obtain certain breeding information on outstanding individuals and studs. The points upon which data were requested included: For draft breeds—plan of breeding, services per mare and foals produced, weight at birth, measurements at birth, ages when subsequent measurements are taken, height, temperament, action, muscling, strength, stamina, symmetry of conformation, feed consumption, and soundness; for light breeds—plan of breeding, services per mare and foals produced, weight at birth, measurements at birth, when subsequent measurements are taken, height, temperament, action, symmetry of conformation, speed, gaits, length of neck, slope of shoulder, length of pastern, shape of foot, set of legs, quality of bone, and soundness. In addition each station was asked: (1) Whether a progeny-testing method was used; (2) to submit a list of horse-breeding project activities; and (3) to submit names and addresses of owners of studs having a reputation for developing superior breeding stocks. With this information it would be possible to summarize the research achievements in the field of horse breeding as a background for the development of well-rounded plans for further investigation.

The Status of Scientific Work on Inheritance in Horses

THE questionnaires indicate that 18 States are doing no work in horse breeding, while 21 States maintain studs, usually for classroom work. Percherons were found in most of these, Belgians in many of them, Clydesdale and Thoroughbreds each in two, and Arabian horses in one. Nine States made no report.

Few of these States have experimental projects that involve a distinct genetic approach to horse breeding. The work being done either concerns the physiology or pathology of reproduction in connection with college work, or the recording of limited data. Colts are weighed at birth and at more or less regular intervals thereafter. A few stations record height at withers and some record heart girth (circumference of chest), circumference of fore and hind cannon bones, color, markings, and such data as mating and foaling dates and feed and work records.

Much more is known, of course, about the horses in a stud than is indicated in the recorded data. Many of them are studied and judged critically by classes in animal husbandry, and the peculiarities of their form, action, and temperament are known to instructor and student.

A few stations conduct experiments aimed largely at finding out the cost of producing colts. Such stations record feed consumption and other costs, but primarily for the information this will give on management methods. Also, some stations reported records that yield information about the breeding efficiency of their stallions and mares. On the average, two services are required for each colt produced.

A BRIEF REVIEW OF RESEARCH IN HORSE BREEDING

A survey of the literature reporting current and recent research work with horses reveals a considerable number of experiments on the physiology of mating and reproduction, particularly in the United States, Great Britain, the Union of Soviet Socialist Republics, Germany, France, and Japan; several experiments for improving technique in the practice of artificial insemination; a few studies of the inheritance of color; an occasional one attempting to correlate body measurements or other factors with constitution and performance; and one study of blood groups in the horse and their inheritance.

Hart and Cole (*10*)[1] of the California Agricultural Experiment Station have developed a method for diagnosing pregnancy in mares as early as 42 days after breeding that is sufficiently practical for use by stables where intensive breeding of valuable horses is being done. By its use it should be possible greatly to reduce the uncertainty and waste of time in establishing whether a mare has been successfully bred. It should also be valuable in obtaining an early indication of a new stallion's ability to get foals. Other workers (*8*, *9*, *13*, *15*) have made additional contributions to that of Hart and Cole.

[1] Italic numbers in parentheses refer to literature cited, p. 945.

Two workers (*2*) of the Union of Soviet Socialist Republics demonstrated that gravidan, a hormone obtained from the urine of the pregnant mare, is of practical use in inducing ovulation in mares that have previously failed to come into heat or refused to accept the male.

Eickman (*6*), in Germany, estimated that of 20,000 mares served in the Rhino Province during 1934, as many as 8,000 required treatment for sterility. In approximately 1,000 tests for diagnosis of pregnancy—blood tests from the forty-ninth to the one hundred and

FIGURE 1.—The versatile American farmer is learning to use his horse power in larger units to save man labor and perform the heavy operations on farms such as plowing. This is an eight-horse hitch pulling a three-bottom gang plow. A horse must have the proper temperament to work well in the various types of hitches.

fiftieth day and urine tests thereafter—the percentage of error was 0.9; while 39 percent of the sterile mares yielded to treatment and foaled.

An attempt to measure racing capacity in the Thoroughbred horse has recently been made by Laughlin (*14*) of the Carnegie Institution of Washington, and after several years' work on the problem he has devised a basic formula by which racing capacity may be measured

within certain limits, and mathematical rules that apparently govern its inheritance.

Stone (*19*) of Stanford University, after weighing many lines of evidence, advanced the belief that male Thoroughbred horses as a class surpass the females of that breed in running ability, and that the best of the females are inferior to the best of the males in this respect.

Müller (*17*) in Germany found, after extensive study, that chest length, width, depth, and girth measurements do not give an indication of performance in terms of speed and endurance in horses, because they do not reliably indicate the volume of the thorax or of the vital organs located there. He found some indication of an interrelation in some of these factors—that chest length, for example, is greater in light and riding horses than in heavy draft-type horses.

In a study (*16*) of the significance of shoulder measurements in relation to running performance, Müller also summarized the results of some 20 others, adding a tabulation of his own of some 200 animals. He could find in shoulder measurements no reliable sign of running performance, and concluded that the systems of judging frequently recommended have no scientific basis.

Another German worker, Kaempffer (*12*), reports extensive studies of blood groups in the horse and their inheritance, and found it possible successfully to diagnose paternity in 22 cases out of 82 attempted, on the basis of new agglutinogens which he has demonstrated.

THE NEED FOR UNIFORM DEFINITIONS OF CHARACTER AND PERFORMANCE

On the whole, little definite knowledge exists on the genetics of the horse (*4*, *18*), although he has been bred to greater variety than most other classes of livestock. For instance, coat colors in horses range through many combinations and a number of puzzling degrees of intensity not readily discernible or capable of being expressed in definite terms. In all breeds except the Suffolk, which must be chestnut, there are found most of the usual horse colors, which would indicate that most breeds are heterozygous for color and that most individual horses are heterozygous for one or more of the several genes having important effects on color. Furthermore, although speed and amount of work performed are readily measurable quantities, there is such a lack of satisfactory measures and expressions of a horse's will to perform to the maximum of his ability, the suitability of his nervous temperament for the duties demanded of him, and the part that his training may have played in influencing his inherited abilities, that the geneticist is greatly handicapped in his analysis.

These needs, together with the relatively high cost of the horse as experimental material and his slowness to reach maturity, have prevented finding very definitely what are the correlations between characteristics and performance.

Of cattle we demand meat and milk; of sheep, meat and wool. But of horses we ask power, versatility, speed, endurance, beauty of form and of action, courage, intelligence, and intuition in an amazing variety of combinations—hence the different types, conformations, weights, dispositions, and even colors to be found in the form of

horse flesh. The range runs from the plump, docile Shetland pony, or the harness pony 36 to 40 inches in height, weighing 500 pounds or less and possessing graceful, rhythmic action, to the ponderous draft horse standing 70 or more inches in height and weighing a ton and upwards.

For measuring speed and endurance we have the stop watch; for measuring tractive power, the recently perfected dynamometer; but for weighing many of the less tangible expressions of a horse's ability we must still depend on the judgment of the expert.

In the Thoroughbred and Standardbred, speed is of paramount importance and other characteristics are important only as they contribute to speed. In the saddle and heavy-harness types, beauty and grace of action are predominant requisites, being much more important than speed. In polo ponies and cow horses, agility, intelligence, and temperament have high value, and the rider cannot measure them in absolute terms.

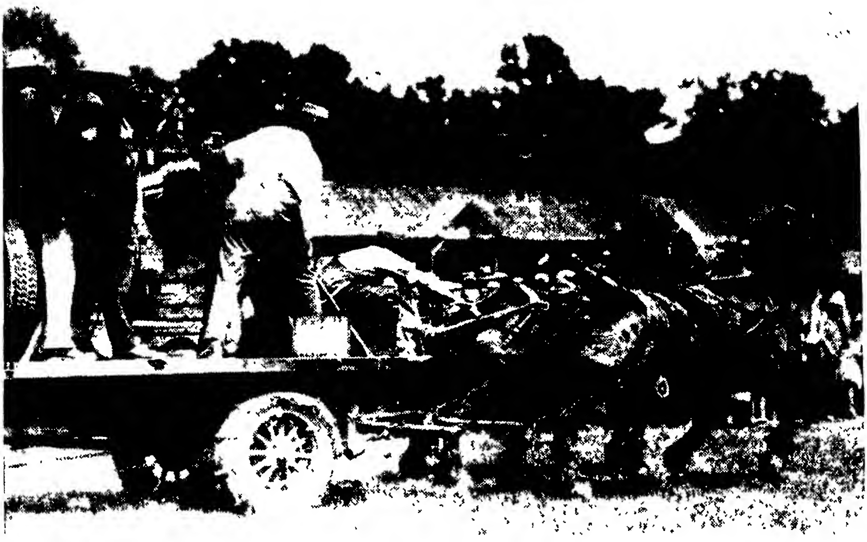


FIGURE 2.—The dynamometer, developed at Iowa State College, has provided a ready measure of the maximum pulling ability of horses. It does not of course measure a team's ability to pull moderate loads over extended periods of time and remain in good condition. Here is a heavy draft team under test.

Even for farm work in a country as varied in climate, topography, soil types, and cropping systems as ours, a wide range in combinations of weight, agility, and temperament is demanded of horses.

Soundness, good health, longevity, and the ability to reproduce are of course desired in all horses. Reproductiveness has received much attention from experimenters and breeders, and a considerable portion of the literature on breeding deals with reproductive troubles involving both sexes. The percentage of the colt crop is often low, yet there are records of extraordinary ability on the part of stallions to get foals.

Trueness of action is emphasized by breeders of horses of all types. Straight action and a good, energetic, free stride are desired because they are usually associated with efficiency. They indicate ability to

work at a rapid pace, and to give long service without lameness or undue fatigue. In addition, grace of action or "style" is essential in light horses ridden or driven for pleasure.

AMERICA'S CONTRIBUTION TO THE BREEDS

The outstanding and characteristically American breeds of horses developed in this country are the Standardbred or American Trotter, descended from a strain of the Thoroughbred breed in which speed at the trotting and pacing gaits is paramount; the American or Kentucky Saddle Horse, developed from the Thoroughbred with some infusion of Morgan inheritance, in which easy gaits under saddle and beauty of form have become characteristic; and the Morgan horse, also of Thoroughbred extraction, a type famous for stamina and sturdiness, developed in New England. At one time a type that fulfilled the requirements for an ideal cow pony, known as the "Quarter horse," was developed in the western range country, though it never reached the stage of recording pedigrees in a studbook. It got its name from the fact that it was very fast for short distances, up to a quarter mile.

No distinctly American breed of draft horse has been produced. The American breeder, however, has ingeniously adapted the predominant European breeds—the Percheron of France and the Belgian Draft of Belgium—to American conditions. Both breeds have been bred in this country to give more agility and a faster walk than the more ponderous European type. The latter is often used with a one-horse cart and is worked for shorter distances than horses usually travel in this country. The Clydesdale, Shire, and Suffolk breeds of Great Britain have also been imported and bred in considerable numbers in the United States.

Recently this Department has imported two stallions and four mares of the Nonius breed from Hungary. This breed is descended from a stallion of that name brought to Hungary from a State stud in France in the time of Napoleon. The original Nonius was by a Thoroughbred out of a Norman mare, and his descendants today are of two types—an upstanding, big-boned farm type, and a lighter type, described as "harder and better," which has made excellent records in Hungary in endurance and speed competitions. Both types are represented in the importation, and they will be used for breeding research.

Practical Measures That Look toward the Improvement of Draft Horses

PRACTICAL breeders and friends of the horse have not idled while the geneticists have been "calibrating their instruments." The colleges have trained students; extension services have promoted contests and demonstrations among farmers to illustrate the marks that can be made with the accuracy of sights now available; and horse and breeders' associations generally have been active in promoting the several breeds.

The most common measure of performance in draft horses has been the tractive dynamometer developed by Iowa State College for

testing maximum pulling power. Since 1923 it has been used at various fairs, horse shows, and special pulling events, and the data secured have been analyzed to determine what characters may be associated with pulling ability. Dawson (*5*) of Illinois found that the weight of the horse had more influence on pulling ability than any other factor studied. Heart girth is important chiefly as it reflects ability to maintain a heavy pull for some distance. Henderson and Ikeler (*11*) of Utah found that "sensible teams with great mental and nervous energy have been perhaps more successful than those of a quiet, easy-going nature." They found no correlation between body type and pulling power, citing as illustrations a champion heavy team that was upstanding and leggy, while the champion light team in the same contest was of the short-legged, heavy-bodied type.

Extensive studies at Iowa (*3*) of the maximum short pull and the less strenuous but continuous pull have shown that it is possible for horses to exert a tractive effort of one-tenth to one-eighth of their weight and travel a total of 20 miles a day without undue fatigue. However, for a short time it is possible for a well-trained horse to exert an overload of over 1,000 percent.

Much remains to be done to eliminate variables before critical studies can be made with the dynamometer. Horses should be given similar training before being tested; they should be made to pull singly; their condition of flesh and of health should be carefully recorded; and the footing and type of shoeing should be similar in all cases. Some measure of temperament, the relationship of temperament to momentum of pull, and of this in turn to pulling ability, should be agreed on. If the test is to have its greatest value, the breeding of all horses tested should be definitely known and recorded.

A demonstration of the value of breeding as well as of feeding and management in the production of draft horses has now completed 10 successful years in Indiana. It is known as the Hoosier Gold Medal Colt Club and is sponsored by Purdue University in cooperation with the Indiana Livestock Breeders' Association. Awards are made for outstanding individual colts and get-of-sire groups based on show-ring judgings, with a minimum requirement for gains in weight during the 12 months following weaning. The project began in 1926 with 96 members in 28 counties entering 137 colts. In 1935 a total of 936 members in 45 counties entered 1,273 colts.

An outgrowth of the work has been the scoring of the sires of the colts on the basis of the colts' achievements, with annual recognition of the high-scoring sire of each breed and of all breeds. This has resulted in virtually State-wide competition among breeding stallions based upon offspring performance, and has also extended general interest in breeding, in culling, and in get-of-sire competition.

There have been some outstanding achievements in consistent performance by winners in this competition. The junior champion Percheron stallion at both the 1935 Indiana State Fair and the 1935 International Live Stock Exposition represents the third generation of an unbroken line of winners in the project, while this stallion's dam, granddam, and great granddam each had a yearling in competition in 1935. For the Belgian breed, a mare, Lady Camille, herself a daughter and great granddaughter of champion stallions at the International, has two generations of consistent winners in Hoosier Gold Medal Colt Club competition and at major fairs and horse shows.

The project has resulted in clarification of aims and improvement in breeding and work stock among Indiana farmers, and has shown indications of a tendency for certain superior qualities to persist in some lines of breeding. Show-ring placing is, however, a relative matter rather than a definite measure of character expression and can be of little genetic value as it is at present determined and regarded. The situation in this respect is no worse for horses, however, than it is for many other classes of animals shown extensively in the ring.

Horse breeding naturally lends itself to community effort since one stallion will suffice for the service of mares owned by several breeders. This has both advantages and disadvantages for improvement. One disadvantage is that the owner of the stallion standing for public service frequently has little immediate interest beyond the service fee. It would be well to have some control of the breeding qualities of such sires to prevent undesirable heredity from being widely distributed. A movement for such regulation and licensing of public-service sires was inauguarted by the State of Wisconsin in 1906. Today, 22 States have such laws, though there is a distinct lack of uniformity in their construction. This is manifested, for example, in the varying definitions of unsoundness. A clarification and general agreement on the specific types of unsoundness that are hereditary would assist materially in adding effectiveness to these statutes.

A total of 13,753 stallions, of which 9,666 were classified as purebreds, were licensed in 1934 under these State enrollment laws, and since in many instances the stallions are under the close scrutiny of active secretaries of the enrollment boards, the sires outstanding on the basis of apparent performance are probably known to some extent.

Improvement in Light Horses—A Notable Record Difficult to Interpret

IN THE light-horse industry, particularly in those branches of it associated with sport, there is a vast amount of earnest and privately endowed effort to produce and locate superior germ plasm, most of it by the well-known trial-and-error method of breeding the "best" to the "best" and hoping for the best. There has been little success in establishing definite relationships between form and other characters and performance. On the one hand is the highly accurate, electrically controlled measure of elapsed time; on the other, the immeasurably variable impressions that can reach man's brain through the retina of his eye and be cataloged there.

Even with a wealth of facts and ingenious instruments at his disposal, the geneticist has a job ahead of him. But it is also generally admitted that the breeder already has achieved some handsome results by trial-and-error methods.

An important project in light-horse breeding, known as the Military Horse Breeding Project, was inaugurated by the Bureau of Animal Industry of the Department of Agriculture in 1912. It was developed for several years in cooperation with the War Department

and transferred to that Department in 1920. It is now supervised by the Remount Service of the Quartermaster Corps and is the instrumentality for distributing approximately 700 stallions of the light breeds, principally Thoroughbreds, for public service. These stallions are located throughout 38 States, Puerto Rico, and Hawaii. Table 1 lists the stallions assigned to agents in the field for public service but does not include stallions at remount depots:

TABLE 1.—*Stallions assigned to field agents for public service and breeding results, 1931–34*

Year	Stallions at stud	Mares bred	Foals produced
1931	630	16,500	9,900
1932	638	16,600	9,960
1933	678	18,300	10,980
1934	691	17,100	[1]

[1] Data not assembled.

Another breeding project of unique character was founded at the United States Morgan Horse Farm, near Middlebury, Vt., in 1907 when Joseph Battell, a lifelong admirer of Morgan horses, presented the Department of Agriculture with a tract of 400 acres to be used as a center for concentrating the best Morgan blood and preventing the extinction of this once popular breed. From this farm, which has been enlarged to about 1,000 acres, hundreds of Morgan breeding animals have been distributed to all parts of the Union and of the world. The farm maintains a stud of about 60 animals.

An interesting series of record-of-performance tests for different breeds and types of horses intended for cavalry use was the "endurance rides" sponsored by various horse associations. These tests were conducted from 1919 to 1926. The distance of the annual tests was 300 miles, and the awards were made on a basis of 60 percent for condition of the horses that finished and 40 percent for speed.

The records obtained were principally body and leg measurements, though the horses were closely observed while in the 5-day test and notes were made of their performance, including respiration, pulse, length of stride, evidence of fatigue or lameness, and appetite. A brief summary of these tests is given in table 2.

TABLE 2.—*Summary of records of endurance rides, 1919–26*

Breed	Horses starting	Horses finishing		Average height	Average weight	Horses having leg trouble		Percentage of own weight carried	Speed per hour
	Number	*Number*	*Percent*	*Hands*[1]	*Pounds*	*Number*	*Percent*		*Miles*
Arabian	14	7	50	15	860	2	14	26	5.4
Do.[2]	11	8	73	15	954	4	36	24	5.7
Thoroughbred	22	9	41	16	1,024	18	62	23	6.5
Do.[2]	46	21	46	16	1,060	33	72	21	6.3
American Saddle	7	3	43	16	1,000	4	57	23	6.6
Morgan	23	11	48	15	918	10	42	25	6.0
Do.[2]	13	5	38	15½	1,036	7	54	22	6.3
Anglo-Arab	9	3	33	16	1,000	5	56	23	6.5
Standardbred	3	0	0	15	900	1	33	25	5.3
Total	148								

[1] 1 hand equals 4 inches.
[2] Grade.

RECORDS OF SPEED PERFORMANCE

The first extensive records of performance for any farm animal were the speed records of the Thoroughbred horse, which go back in one form or another for 200 years.

The history of trotting-horse racing in the United States dates back over a period of 130 years, and for more than 50 years Wallace's Trotting Register has recorded speed records for the Standardbred.

FIGURE 3.—In honor of the progenitor of a famous breed of American horses—the Morgan. A statue of Justin Morgan donated by the Morgan Horse Club of America and erected in 1921 on the United States Morgan Horse Farm, Middlebury, Vt., on the 100th anniversary of his death.

A century and a quarter of trotting records shows a consistent improvement in speed, although it is impossible to determine what part of this can be credited to superior inheritance for speed.

It is recorded that in 1806 a horse named Yankee was the first to cover the mile distance in less than 3 minutes, trotting. His time was 2:59, which he reduced to 2:49½ in 1810. These races and others at that time were done under saddle, and it was not until the 1840's that the first authentic instance of trotting to a sulky was recorded.

This was at Boston, Mass., where the mare, Lady Suffolk, was credited with the first mile record under 2:30.

Gradually the record crept downward, and it had reached 2:08¼ when, in 1892, the high-wheeled sulky was replaced by the modern, pneumatic-tired racing sulky. In 1903, at Readville, Mass., with this equipment and lighter harness, Lou Dillon finally achieved the 2-minute mark. Since that date about 20 trotters have raced a mile in 2 minutes or less. The best trotting record to date is 1:56¾ made by Peter Manning against time in 1922.

The first 2-minute mile by a Standardbred pacer was recorded by Star Pointer in 1897, and some 30 pacers have equalled that mark or bettered it since. The present record of 1:55 was set by Dan Patch in 1906—preceded by a runner to sulky carrying a windshield.

FIGURE 4.—Testing horses for endurance. A scene on one of the endurance rides which were sponsored by several organizations interested in the improvement of saddle horses for remount purposes.

It is interesting to note that the rules for admission of Standardbred horses to registration, as originally established in 1879, are quite different from those used in other classes of livestock. Performance was given equal weight with pedigree as the open sesame to registration, and studbook entry was allowed to individual animals on the basis of speed performance—their own or that of their progeny—regardless of breeding. In effect, such rules threw great emphasis on individual selection, based on performance and progeny test, in comparison with the usual livestock registration rules, which put the emphasis primarily on pedigree—in one sense exclusively, since animals without proper pedigree can never be admitted.

These original rules also allowed registration to animals whose pedigree showed 75 percent of Standardbred blood, even without an approved speed mark. This provision was dropped for horse colts

in 1887. In that year, and again in 1891, 1892, 1893 (effective in 1895), 1898, and 1930, revisions were made in the requirements for Standardbred registration, with a gradual tightening until, effective January 1, 1933, registration on the basis of performance alone was no longer granted. Today a Standardbred horse, to be eligible to registry, must be by a registered sire out of a registered mare.

Of chief interest, perhaps, is the fact that throughout the long period when admission to Standardbred registry was available to the grade or cross-bred animal who could, either itself or through its progeny, equal certain speed standards, such grades and cross-breds generally were unable to make the goal. For a third of a century and more the increasingly rigid performance standards that have been set for Standardbreds have operated as an effective barrier to all animals not carrying an overwhelming percentage of Standardbred blood in their immediate ancestry.

The improvement in record-making performance has been undeniable. It would be extremely difficult, however, to attribute any definite portion of it to the segregation of superior germ plasm. Better management, faster vehicles, lighter and improved harness, faster tracks, and sampling from greater numbers of animals have also been factors. On the other hand, of twenty 2-minute trotting records and thirty 2-minute pacing records achieved in a period of nearly 40 years, 13 trotting and 18 pacing records have been made in the past 15 years when fewer Standardbreds have been in use than formerly. Moreover, it is rather generally agreed by harness-horse owners and observers that 2- and 3-year-old trotters and pacers now commonly set marks that would have been prized by older horses a few years ago running under essentially the same conditions. This would seem to indicate an improvement in average excellence at least.

HOW GREAT SIRES CARRY ON THROUGH THEIR PROGENY

American horse-breeding annals do, however, offer convincing records of the ability of great sires to "carry on" through their progeny. Of all such examples, especially when viewed from the standpoint of their influence on a breed, none is more significant than the contribution of Hambletonian 10.

This famous Standardbred sire, a son of Abdallah and a descendant of the imported Thoroughbred stallion Messenger, was foaled in New York State in 1849. During his lifetime he is reported to have sired more than 1,300 foals; through one period of 7 years (1860–66) he got 714 colts from matings with 1,027 mares, an average of more than 100 foals a year. In 1865 the price of his service was $300, and he covered 193 mares. In 1866 the price was advanced to $500, and he served 105 mares. In 1870, when he was 21 years old, he covered 22 mares and got 13 foals. He got two foals in 1875 and died the following March.

Hambletonian 10 was one of the greatest horses that ever lived, when measured by offspring performance. He was photographed at rest and in action, and every known measure was used to discover the secret of his greatness. It took more than a thousand words to pen a reputedly accurate description of him that has itself been

subjected to much intelligent and critical review and amendment. He had contradictory points of conformation and character that puzzled the wisest. According to Wallace (*20*), "his two great, meaty ends, connected with a long and perfect barrel, two or three sizes too small for the ends, showed such a marked disproportion that I often wondered at it." The horse's ears were so set that they habitually lopped backward when he was in repose, there was an abrupt, entirely unorthodox, angle to his hocks, and his stride was so much his own as to be termed peculiar, yet when he settled into it there was a supple, frictionless beauty of movement.

Hambletonian 10 laid the foundation for the trotting-horse breed. The ability to transmit harness racing speed did not pass away with him, for other great sires have followed. Two of the most noted of these in modern times are Peter the Great and Guy Axworthy, both descendants of Hambletonian 10. Peter the Great died in 1922, aged 27 years. In volume 44 of Wallace's Year Book (*1*) he is credited with 498 trotters and 163 pacers of standard record, which is 2 minutes 30 seconds for the former and 2 minutes 25 seconds for the latter, for the mile distance. He is also credited there with 172 sons which have themselves sired one or more animals with the required standard speed, while his daughters have foaled 550 trotters and 149 pacers with such records.

Where Peter the Great left off, his sons are carrying on. Three sons alone, Peter Volo, Chestnut Peter, and Azoff, are credited up to 1932 with 520 trotters and 167 pacers with standard speed records. Moreover, these three sires, up to 1932, had 151 trotters and 71 pacers in the 2:10 list.

By the close of the 1931 season, Guy Axworthy had sired 421 trotters and 40 pacers of standard record. He also had to his credit 49 sons which sired standard-record performers, while his daughters produced 186 trotters and 37 pacers with acceptable speed records for this standard.

Measured by more exacting standards, these two great sires continue to demonstrate their ability to hand on their good qualities. In the 2:10 list, Peter the Great has sired 111 trotters and 48 pacers. He sired one pacer in the 2-minute list and the dams of three 2-minute trotting performers. His son, Azoff, sired the world champion trotter, Peter Manning, 1:56¾; and Peter Volo, another son, has four entries in the 2-minute trotting group.

Guy Axworthy, in the 2:10 list, has 143 trotters and 13 pacers; in the 2-minute list, 4 trotters. His four sons that are 2-minute performers or better are: Lee Axworthy, 1:58¼; Guy McKinney, 1:58¾; Mr. McElwyn, 1:59¼; and Arion Guy, 1:59½.

To illustrate the influence of a great Thoroughbred sire which transmitted heredity for many of the characters influencing speed, the record of Domino is cited (*7*). This stallion died at the early age of 6 years after only two seasons in stud, and produced only 20 foals, 6 born in 1897 and 14 in 1898, yet the name of Domino in direct male line is found in the pedigrees of such great performers of today as Balladier, Black Helen, Boxthorn, Equipoise, Mata Hari, Observant, and Riskulus.

The Mule—An Outstanding Example of the Practical Use of Hybrid Vigor

THE mule is the classic example of the deliberate and widespread use of hybridization for producing stock in which vigor is an important consideration. The cross has shown consistently uniform results. From its horse ancestry it inherits substance and size, and to some extent alertness. From its ass ancestry it gets its steady-going qualities, sure-footedness, and the ability to withstand long

FIGURE 5.—Our hybrid servants—mules—have no "pride of ancestry or hope of posterity" but the breeding of "superior" jack stock and the availability and selection of proper types of mares is a splendid field for reasearch by our experimentalists.

periods of hard labor in hot climates, in mines, and under similar adverse conditions.

In the United States one of the earliest and most influential sponsors of the mule was George Washington. In 1785, a jack and two jennets of the Andalusian breed, gifts from the King of Spain, arrived at Mount Vernon. This was the first recorded jack-stock importation in American history. Later Washington received a Maltese jack and

jennet from the Marquis de Lafayette. Washington bred the Maltese jack to an Andalusian jennet. The progeny, which he named Compound, was the first "all-American" jack. This jack sired some excellent mule stock, and the value of the mule as a work animal was soon recognized by the early planters.

It is only within the last half century, however, that the production of mules has become an extensive enterprise. Mule breeding is carried on mostly in Texas, Missouri, Oklahoma, Tennessee, Kansas, and Kentucky. These States, together with Illinois, Iowa, and Arkansas, raise about 75 percent of all mules in the United States. Mules are used most extensively in the Cotton Belt States.

For some purposes, such as work in the sugarcane sections, heavy draft mules are desired, but the development of the truck and tractor has in recent years brought severe competition in this work. As a result, the market preference for large mules is not so strong as it used to be, although it still exists. The heavy draft mules are produced from mares of draft breeds, principally Percherons and Belgians, and the smaller mules from mares of the light breeds and types that carry considerable Standardbred, Thoroughbred, and other light blood. Because of the premium on size in mules, height has been one of the important considerations in selecting jacks and jennets, and it is recorded in the pedigree studbooks.

It is widely recognized that mules are almost always sterile, and for this reason matings intended to produce a desired type must be made by the intelligent selection of jacks and mares of the right type. The few authentic cases of fertile mare mules [2] are of great scientific interest, but the high percentage of sterility is a serious obstacle to progress in breeding such animals, though the subject deserves investigation.

The ideal in jacks and jennets has so far been mainly concerned with height and large smooth bone, with some attention to action and straightness of legs. American mule breeders have achieved remarkable success in producing probably the best mules in the world, but the supply of good jack stock has diminished to such an extent that importation has again been resumed after a lapse of 25 years.

In performance tests with the dynamometer, mules have been disappointing by comparison with horses, although, like horses, they have demonstrated their tremendous reserve of power. At Fort Des Moines, Iowa, in 1924, a team of four Army mules, hitched tandem in two pairs, developed a tractive pull of 2.74 horsepower per mule as against 6.97 horsepower per horse for a six-horse team of horses of similar size. The mules pulled so slowly that they were unable to produce continuous motion over the required distance of 27½ feet for a large proportion of the heavy loads they could start. This again demonstrates the ineffectiveness of the dynamometer, as now used, to measure the ability of animals to endure a hard day's work. The mule, moreover, is phlegmatic and a creature of great stubbornness. He will not do his best without strenuous urging, and he will work harder in fear of the whip than under its sting. In all official pulling contests, all types of urging by drivers, such as use of whips and shouting, are prohibited.

[2] See Unusual Possibilities in Breeding, p. 183.

Superb Breeding Material, Awaiting a Greater Background of Knowledge

FOR no other class of livestock do we have such a wealth of recorded achievement as for the horse. The greatest of his species have given us brilliant marks to shoot at, in performance, in the ability to transmit desirable characters, and in longevity. As with all livestock, the disappointing performances go largely unrecorded. Yet they occur, and many a great performer has been a failure when measured by his progeny.

The failures are apt to be laid at the door of the animal's germ plasm. It is the least visible thing about him and therefore the most safely blamed. But may not some of them have environmental causes? Possibly serious errors in early training or in feeding have disturbed or altered the function of a vital gland. Certainly the horse is a highly complicated mechanism, and consequently subject to derangement.

FIGURE 6.—A Belgian Draft stallion and his get, showing offspring of different ages left to right: Colt, 1-year-old, 2-year-old, 3-year-old, 4-year-old, 5-year-old, 6-year-old, 7-year-old, 8-year-old, and the sire, Rowdy, at extreme right. This illustration shows the uniformity of get of a "superior" sire from various matings, and the ability of this sire to transmit his good qualities to his offspring though the dams are of different breeding and types of conformation.

In many countries today the horse is receiving increasing attention from scientists. The endocrinologist especially is finding here a fertile field for experimentation. Most of his work to date, however, has been therapeutic, with no permanent hereditary effect. Unless he coordinates his work with that of the geneticist, some of his effort will tend to perpetuate undesirable germ plasm, and much of it will fail to improve the horse's inheritance. The same hormone that is used to extend the fertile life period of a great sire for which we have a progeny test and which has demonstrated longevity, will enable another sire with inherent tendencies toward sterility or other shortcomings to perpetuate his weakness in offspring.

Economic depression has emphasized anew the basic reliability and flexibility of animal horsepower for many types of farm work and the importance of breeding for better performance. The military depart-

ments of many nations are giving increased attention to improvement in saddle and artillery types. The field of sport is making ever-increasing and well-endowed demands of the horse, especially running breeds and polo types.

When the science of animal genetics has a background of greater experience, and when it reaches the point where it is eager to test its theories on a species of amazingly varied kinds and degrees of performance—some exactly measurable, others difficult if not impossible to define and measure accurately—the horse will offer excellent raw material.

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Appendix

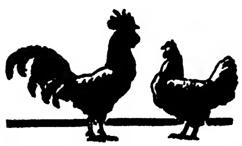
Some Workers Identified With Horse Improvement at State and Federal Agricultural Experiment Stations and Other Institutions

At State agricultural experiment stations:
- California, Berkeley: C. W. Howell.
- California, Pomona: H. H. Reese.
- Connecticut, Storrs: H. L. Garrigus.
- Georgia, Athens: M. P. Jarnagin.
- Illinois, Urbana: J. L. Edmonds.
  C. W. Crawford.
- Indiana, Lafayette: R. B. Cooley.
  P. T. Brown.
- Iowa, Ames: A. B. Caine.
  J. L. Lush.
- Kansas, Manhattan: C. W. McCampbell.
- Kentucky, Lexington: W. W. Dimock.
  W. S. Anderson.
- Michigan, East Lansing: R. S. Hudson.
- Minnesota, St. Paul: W. H. Peters.
  A. L. Harvey.
- Missouri, Columbia: E. A. Trowbridge.
- Montana, Bozeman: D. W. Chittenden.
- New York, Ithaca: M. W. Harper.
- Ohio, Columbus: D. J. Kays.
- Oklahoma, Stillwater: W. L. Blizzard.
- Oregon, Corvallis: B. W. Rodenwold.
- Texas, College Station: D. W. Williams.
- Wisconsin, Madison: J. G. Fuller.

At other institutions:
- United States Remount Service, Fort Douglas, Utah: G. A. Bell.
- Carnegie Institution of Washington: H. H. Laughlin.

United States Department of Agriculture:
- United States Morgan Horse Farm, Middlebury, Vt.: E. B. Krantz.
- United States Range Livestock Experiment Station, Miles City, Mont.: E. B. Osborn.
- Bureau of Animal Industry, Washington, D. C.: J. O. Williams, S. R. Speelman.

Superior Breeding Stock in Poultry



By Morley A. Jull, Senior Poultry Husbandman, in charge of Poultry Investigations, Animal Husbandry Division, Bureau of Animal Industry

CONDUCTING a survey for the purpose of locating superior breeding stock among the poultry flocks of the United States and other countries turned out to be an interesting and instructive undertaking.

In some respects, more progress has been made in the development of breeds of chickens than is the case with any other class of domestic livestock. As compared with cattle, sheep, and swine, all of which are used to produce food for human beings, the chicken is a small creature, and one that is capable of reproducing itself in relatively large numbers. Intense selection is therefore possible, and if proper care is exercised considerable progress can be made in a relatively short time in combining a number of desired characteristics, both those that are of economic importance and those that are not. There is a widespread impression that great progress has been made in poultry breeding in modern times, and in a very real sense this is true. Yet it is also true that for the most part the data submitted on the survey forms were so meager as to be practically valueless in the search for stock of superior breeding worth. As for foreign countries, very few replies were received from the breeders to whom the survey records were sent.

Though this lack of results is significant and striking as a bald fact, too hasty conclusions should not be drawn from it. A quest for poultry stock of superior breeding worth is bound to be extremely difficult because there are thousands of poultry breeders and different standards are involved. For the most part, breeders are concerned not only with the number of eggs laid but also with their size, shape, and hatchability, and with such matters as the size of the birds and the extent to which they conform to the standards for the breed or variety being kept. Birds that do not come up to par in one or more respects are often culled from the flock, and rarely does it happen that a poultry breeder keeps all of the progeny of a given mating. For economic reasons he is obliged to cull the loafers among his layers, and since small eggs are objectionable from a market standpoint, birds that lay small eggs are not kept for breeding purposes. In most flocks so much culling is practiced that it is a very difficult matter

to secure an accurate index of the breeding worth of the sires and dams; for superior breeding worth is not a matter of producing a few good layers—it is a matter of getting high average production in all of the progeny of the breeding stock.

The survey showed that practically all poultry breeders cull their pullet flocks rather stringently. In fact, the culling is so stringent in many flocks that an analysis of the results obtained was out of the question. Some breeders have been using as few as 20 to 30 female breeders each year. Quite a number trap nest a portion only of the pullets raised from their pedigree matings. Again, most of the breeders to whom the survey records were sent had never determined the average egg production of the pullets that were allowed to finish their first laying year; they could give only the production records of the pullets that qualified for official Record of Performance. In the case of many flocks, then, the records kept are far from complete. Moreover, some flocks may be noted not only for their laying ability but also for small egg size or poor hatchability.

Finally, from the standpoint of conducting a survey, there is the difficulty involved not only in the large number of progressive poultry breeders, but in the much greater number of breeding birds used. Even in the case of males, this number would run into thousands, for some breeders have from 30 to 50 pen matings each year, and the number of hens would be many times that. Just to list the results obtained over a period of years from the flocks of a score of poultry breeders would be a formidable task. And even with these breeders the story would not be complete, for it is practically impossible to classify the breeding stock with respect to their relative superiority in five or six characteristics which are being bred for simultaneously.

The Present Situation and the Need for Further Scientific Research

NOW the significance of all this comes out very strongly when it is realized that, in spite of the number of breeders and the extent of the breeding stock, the average egg production per bird per year in the country as a whole is abnormally low, being approximately 80 eggs, according to census estimates. Yet the average income per State from poultry products sold in 1929 was about $18,000,000, of which about two-thirds was from eggs and one-third from market poultry. The average farm egg sales in 1929 amounted to $151, whereas the average farm market-poultry sales amounted to $84. According to the census of 1930, over 85 percent of all farms had poultry flocks, so that over 5 million farmers are directly concerned in the future development of the poultry industry. In 1933 the farm value of poultry products amounted to $653,652,000 and accounted for approximately 20 percent of the total farm value of livestock and livestock products. There are approximately 400,000,000 adult chickens kept annually on American farms, and they produce eggs at the rate of about 60,000 every minute, day and night. From insignificant beginnings poultry raising has developed until it is now one of the most important branches of agriculture.

Many poultrymen fail to realize that heredity is inescapable. Every year too many poor producers are kept and used for breeding. Mediocrity tends to reproduce itself, and if egg production is to be increased, the most careful selection of the breeding stock is essential. But the problem goes deeper than this. For the poultry industry as a whole, it is of the first importance to develop strains of fowl that will produce eggs more efficiently. The cost of production and reproduction should be reduced. The very size and wide extent of the industry makes this all the more important.

How is improvement to be brought about? In industry, commerce, and agriculture alike, progress depends to a large extent on research. Industrial and commercial concerns in many cases have established

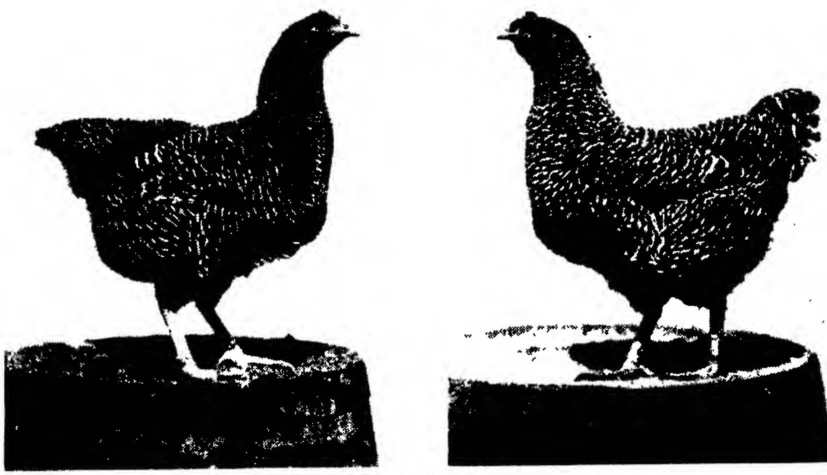


FIGURE 1.—Good egg production is necessary to enable poultrymen to make money out of their flocks. The Barred Plymouth Rock (*A*) laid 236 eggs during her first laying year, and the other one (*B*) laid 233.

extensive laboratories that are well equipped and staffed with research men of high caliber. Agriculture cannot organize research work on this basis. It is dependent, for the most part, on the Federal Department of Agriculture and the State experiment stations to solve problems of the first magnitude facing the industry.

THE HEART OF A PROGRAM FOR FURTHER PROGRESS

In many respects the State experiment stations and other institutions have made notable contributions to the science of poultry raising. In the problems of rearing and feeding, the stations have contributed much scientific information that enables poultry producers to make the most out of such hens as they may have. Important as these things are, however, the intrinsic qualities of the flocks are in no way altered. An ideal environment and a perfectly balanced diet will never make a good layer out of a hen that does not possess the characteristics upon which productivity depends. This is where the art of breeding necessarily enters the picture. The experiment stations should be expected to contribute much to the rather meager fund of

knowledge possessed by most poultry breeders concerning the inheritance of the characteristics that determine productivity, and the size and quality of eggs.

With few exceptions, however, the State experiment stations have done very little in paving the way for the development of stocks of superior breeding worth. At many of the stations, lack of funds makes it impossible to maintain a breeding flock of sufficient size to provide for the adequate selection of breeding stock. A few stations carry on breeding work with three or four different breeds or varieties instead of concentrating efforts on one breed or variety. At most of the stations some culling of the pullet progeny is practiced, and this, as will be made clear later, materially lessens the value of the results obtained.

What most poultry breeders want to know is how to develop males and females of superior breeding worth so that they can be used to

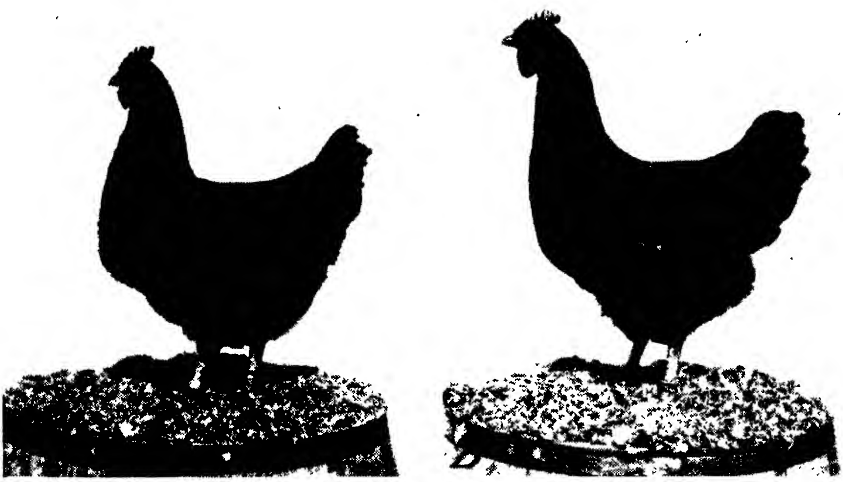


FIGURE 2.—Well-bred birds are a good investment. Here are two Rhode Island Red granddaughters of a good female. One (*A*) laid 263 eggs and the other one (*B*) laid 284 in a year.

raise the level of egg production and increase the average size and improve the quality of eggs laid by the flocks of the country. The poultry breeder also wants to know how to reduce the annual cost of flock replacements; he wants good hatchability and low chick and adult mortality. The experiment stations could render valuable service in this direction by conducting research studies on:

(1) The inheritance of egg production, using a reasonably large number of matings and keeping a random sample of each of the families produced.

(2) How to combine good average egg size with good production.

(3) Whether or not it is possible to develop strains of high layers that are resistant to specific diseases.

(4) How best to combine good hatchability with good egg production and good egg size.

(5) Whether or not any inbreeding is desirable or necessary to develop high-laying strains; that is, is it advisable to secure a relatively high degree of homozygosity as a step in producing breeding stock of superior worth?

(6) Whether or not worth-while results in breeding for increased egg production, good egg size, and improved interior quality can be secured through cross-

breeding; that is, is heterozygosity which is kept under control likely to secure the desired results?

(7) The extent to which environment rather than inheritance may be responsible for the variability that normally occurs in breeding for quantitative characteristics, such as egg production.

(8) The best methods of selecting breeding stock to accomplish the objects sought, and of giving proper weight to records of production, pedigree, and progeny test.

There are valid reasons why research workers should take the lead in the solution of these vital problems, which may well be considered the heart of any program for further progress. For economic reasons, most private poultry breeders cannot afford to experiment with matings merely for the sake of finding how things will turn out. The poultry breeder has to count the cost, and it is most natural for him to mate what he believes to be the best to the best on the chance that he will get the desired results. Trap-nesting and pedigree breeding is time-consuming and expensive, and since most poultry breeders have

THE production record, the pedigree, and the progeny test provide three means of identifying the dam of superior breeding worth. A superior sire is identified by the production record of his dam, his own pedigree, the average egg production of his full sisters, and the kind of progeny he produces. It can be said with a reasonable degree of certainty that in the present state of the poultry-breeding industry of the United States, the selection of breeding stock on the basis of the progeny test is the most important step in the development of a balanced breeding program.

to make a living out of their work, they can hardly be expected to keep all the progeny secured from different matings, or even to keep a random sample. But a random sample is necessary if an accurate index is to be obtained of the breeding worth of a mating or a flock, and it is the business of the experimenter to retain a random sample for the purpose of getting at all of the factors involved. Nor could the private breeder afford such an experiment as submitting a diverse flock to the worst possible environmental conditions, including disease, to see what might emerge from the trial in the way of resistant stock. Yet an experiment of this sort might yield some very significant results.

In other words, there are numerous problems that poultry breeders, if left to themselves, could never solve. A comprehensive project on the effects of varying degrees of inbreeding on egg production, hatchability, and other characteristics is outside their field. They could probably never solve the principles involved in cross-breeding, however important such problems may be in practical breeding

operations. They should never be expected to undertake experiments to determine whether or not it is possible to develop disease-resistant strains. For many reasons, it is clear that if a number of problems of major importance facing the poultry-breeding industry are to be solved, the work must be undertaken by the scientists.

Progress in Tracing the Inheritance of Traits in Poultry

RESEARCH in such problems is in line with what has already been accomplished by the Federal and State experiment stations. They have not by any means been idle in genetic research,

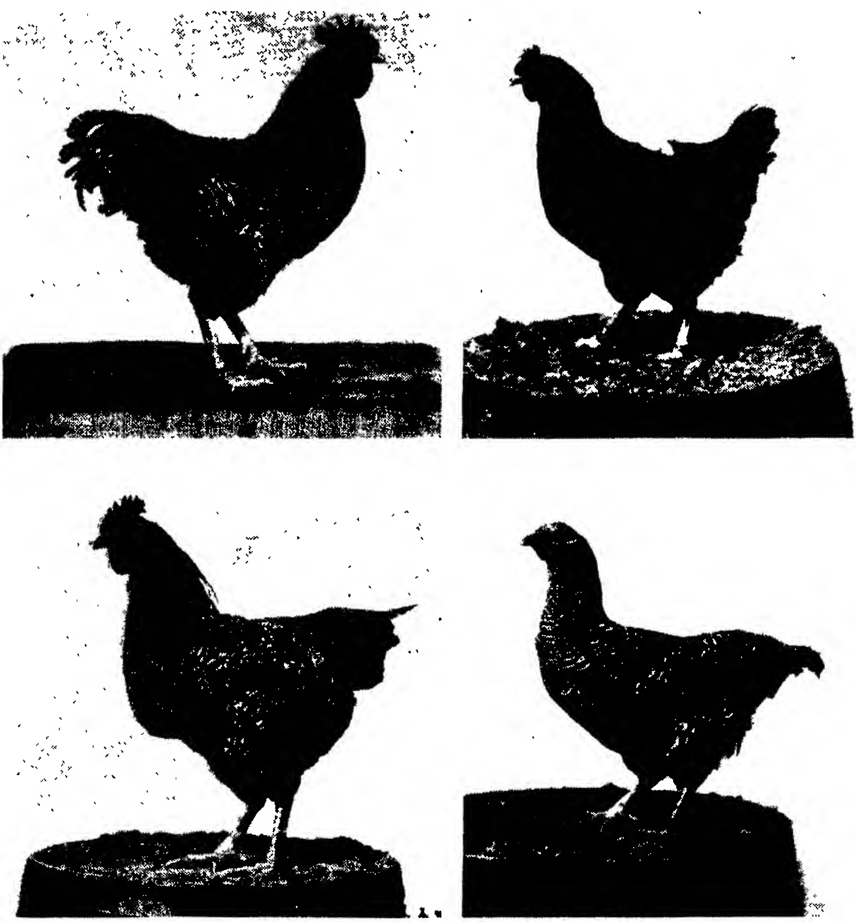


FIGURE 3.—The barring of the Barred Plymouth Rock is dominant to nonbarring. When a Barred Plymouth Rock male is crossed with a Rhode Island Red female, the male and female adult progeny are barred because the sire has a gene for barring on each of his two sex chromosomes, one of which is transmitted to each of his sons and the other to each of his daughters: *A*, Barred Plymouth Rock sire; *B*, Rhode Island Red dam; *C*, adult son; *D*, adult daughter.

and they have made contributions to scientific knowledge concerning inheritance in poultry. The manner of the inheritance of a large number of color, morphological, and physiological characteristics have been determined rather precisely.

A few of these are of considerable practical importance. The barring of the Barred Plymouth Rock is dominant to nonbarring and is sex-linked—that is, the factor that determines this characteristic is located in the chromosome that is associated with sex. When a Rhode Island Red male is mated with a Barred Plymouth Rock female, the chicks at hatching time can be separated according to sex, thus making it possible for broiler producers to purchase the cockerels and egg producers to purchase the pullets. The down of the male chicks is black at hatching time except for a white spot on the top of the head, and the beak and shanks are yellow; the down of the female chicks is solid black in color, and the beak and shanks are very dark or almost black. Other sex-linked crosses involving other breeds and varieties can be made. Broodiness has been shown to be due to two dominant, complementary genes, and in at least one breed sex-linked genes have been observed to be involved. Slow rate of feathering is dominant to rapid rate of feathering and is sex-linked.

These are examples of characteristics of practical importance; but it must be admitted that most of the characteristics that have been traced down genetically have little economic significance.

While on the subject, however, it might be well to summarize what these characteristics are. They come under three general headings: (1) Color traits, which are among the most conspicuous of all the characteristics chickens possess and constitute the basis for differentiating the varieties of a breed; (2) morphological traits, which relate to form and size, such as the shape of the comb, the presence or absence of a crest, feathered or nonfeathered shanks, and the type of feathering over the body; and (3) physiological traits, which relate to functional activity, such as hatchability of eggs, broodiness, and rate of feathering.

Most of the traits or characteristics whose inheritance has been definitely traced are listed in table 1. A few words of explanation are necessary. Column 1 gives the trait. Column 3 tells whether the factor or gene that determines this characteristic is located in what is known as an autosomal or body chromosome, or whether it is in a sex chromosome (sex-linked). Column 2 tells whether the trait is dominant or recessive.

TABLE 1.—*Dominant and recessive characteristics in chickens*

Characteristic	Dominant or recessive	Autosomal or sex-linked
White plumage	In White Leghorns, almost completely dominant to color.	Autosomal.
Do	In White Dorkings, Langshans, Minorcas, Plymouth Rocks, Wyandottes, recessive to color.	Do.
Do	In some strains of Rose Comb White Bantams and White Silkies, recessive to color.	Do.
Black plumage	Dominant to recessive white	Do.
Blue plumage	Due to heterozygous condition of color genes	Do.
Buff plumage	A multiple gene characteristic dominant to recessive white and recessive to black, and recessive to "silver."	Autosomal and sex-linked.
Silver plumage	"Silver" in Columbian, silver-laced, and silver-penciled varieties dominant to "gold" in red, buff, golden-laced, and golden-penciled varieties.	Sex-linked.

TABLE 1.—*Dominant and recessive characteristics in chickens*—Continued

Characteristic	Dominant or recessive	Autosomal or sex-linked
Barred plumage	In Plymouth Rocks, dominant to nonbarring	Do.
Do	In Campines, dominant to nonbarring	Autosomal.
Red-splashed white plumage	Recessive to solid color and to color pattern	Do.
Albino	Recessive to normal	Do.
White skin and shank color	Dominant to yellow skin and shank color	Do.
Dark skin and shank color	Recessive to nondark skin and shank color	Sex-linked.
Rose comb	Dominant to single comb	Autosomal.
Pea comb	do	Do.
Walnut comb	Dominant to rose, pea, and single comb	Do.
Side sprigs	Dominant to normal comb	Do.
Cerebral hernia	Recessive to normal cranium	Do.
Crest	Dominant to absence of crest	Do.
Muff and beard	Dominant to absence of muff and beard	Do.
Naked neck	Dominant to normal neck feathering	Do.
Feathered shanks	Dominant to nonfeathered shanks	Do.
Vulture hock	Recessive to normal hock	Do.
Rumplessness	Dominant to normal condition	Do.
Long tail	Incompletely dominant to normal tail	Do.
Hen feathering	Dominant to normal feathering	Do.
Frizzle plumage	Incompletely dominant to normal plumage	Do.
Silkie plumage	Recessive to normal plumage	Do.
"Frayed" feathers	Recessive to normal feather development	Do.
Close feathering	Dominant to loose feathering	Do.
Slow feathering	Dominant to rapid feathering	Sex-linked.
Flightless	Dominant to normal wing	Autosomal.
Crooked neck	Recessive to normal neck	Do.
Creeper condition	Dominant to normal condition; lethal when homozygous.	Do.
An embryo lethal	Recessive to normal embryo development; lethal when homozygous.	Do.
"Sticky" embryos	Recessive to normal; lethal when homozygous	Do.
Parietal baldness	Dominant to normal	Do.
Congenital blindness	do	Do.
Congenital loco	do	Do.
Congenital palsy	do	Do.
Polydactyl	Dominant to four-toed condition	Do.
Early sexual maturity	Dominant to late sexual maturity	Autosomal and sex-linked.
Broodiness	Dominant to nonbroodiness	Do.

Among the numerous characteristics listed in table 1, it is apparent that many are what might be called superficial characteristics that have practically no significance in determining the breeding worth of birds used for transmitting egg- and meat-producing qualities to their progeny. A few of the characteristics listed in table 1 are of considerable economic importance and some have a direct bearing on the development of strains of fowls of superior breeding worth. For instance, a poultryman endeavoring to develop a high-laying strain should naturally pay close attention to such characteristics as nonbroodiness and early sexual maturity in the selection of his breeding stock. As time goes on, it is anticipated that the inheritance of other characteristics of economic importance will be investigated.

The Background and the Early History of Poultry Breeding

SO MUCH for the present situation and the present needs in poultry breeding as these stand out under the searching light of an effort to survey superior germ plasm. The problem of developing superior breeding stock, however, must be considered as a whole. While

experimental science has made great contributions and should make still greater ones in the future, much responsibility also lies with the practical breeders. Although poultry breeders have perhaps made greater progress in developing strains of superior breeding worth than breeders of any other class of livestock, it is safe to say that they have not by any means gone as far as they could.

The third section of this article will discuss what might be done by breeders to put into practice certain sound principles developed from present knowledge. But present knowledge has grown out of past practice and experimenting. It would be well, then, to survey earlier developments briefly, in order to get some picture of the progress that has been made and to evaluate the worth of some major developments. This will be done in the following section.

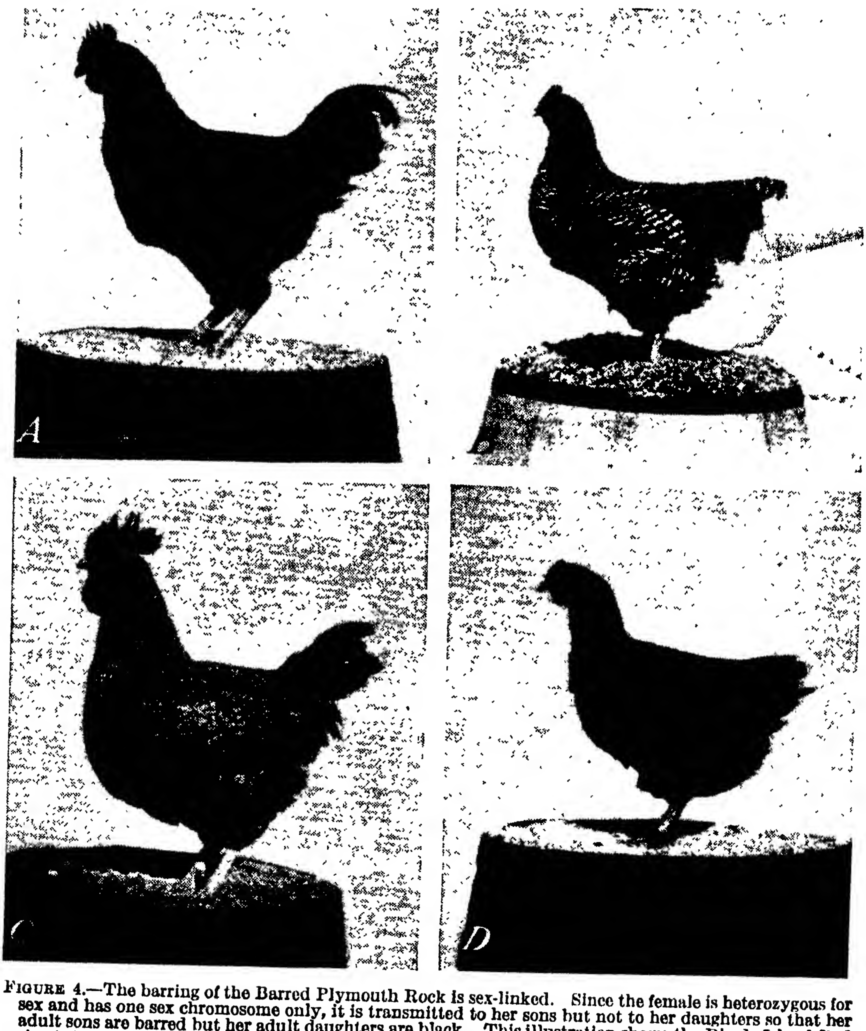


FIGURE 4.—The barring of the Barred Plymouth Rock is sex-linked. Since the female is heterozygous for sex and has one sex chromosome only, it is transmitted to her sons but not to her daughters so that her adult sons are barred but her adult daughters are black. This illustration shows the Rhode Island Red sire (*A*), the Barred Plymouth Rock dam (*B*), the barred son (*C*), and the black daughter (*D*).

No class of domestic livestock offers such a bewildering variety of body types, head furnishings, color patterns, and other characteristics as the domesticated chicken of today. There are chickens with single combs, rose combs, pea combs, walnut combs, red ear lobes, white ear lobes, crests, muffs and beards, feathered shanks, nonfeathered shanks, four toes, five toes, white skin, yellow skin, black skin, silkie feathers, frizzled feathers, white plumage, black plumage, buff plumage, blue plumage, red plumage, and color patterns of various kinds; and there are chickens that lay white-shelled, brown-shelled, and blue-shelled eggs. Take your choice of these and other characteristics, and in due time a chicken could be produced to meet your fancy. Thus, the lordly Brahma, with pea comb and feathered shanks, is a very different bird from the diminutive Rose Comb

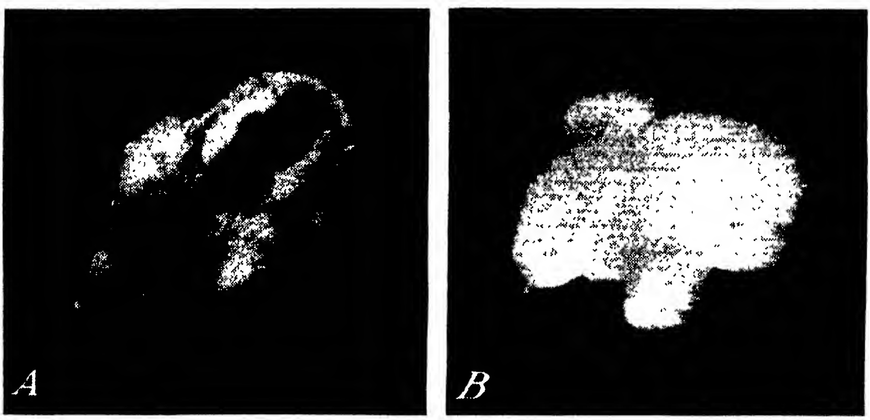


FIGURE 5.—The chicks of a Rhode Island Red × White Plymouth Rock cross can be separated according to sex at hatching time by the difference in down color: *A*, The down color in a female chick secured from the sex-linked cross of Rhode Island Red male and White Plymouth Rock female. As an adult this female will be buff to red in color, perhaps with some striping. *B*, The down color in a male chick secured from the sex-linked cross of Rhode Island Red male and White Plymouth Rock female. As an adult this male will have the Columbian pattern as in the Light Brahma and Light Sussex.

Bantam. The squatty Creeper stands in striking contrast to the upright Exhibition Game that can pick crumbs off a 2-foot table. The Leghorn with its graceful feather contour is quite different in build from the boat-shaped Cornish fowl.

The progenitor of the modern fowl was the wild cock whose call resounded through the bamboo jungles of India. In China the domestication of the cock dates back to as early as 1400 B. C., and in India, when the Aryans had reached the Ganges in 1000 B. C., domestic fowls were quite common. They were transported northward and westward against the line of Aryan invasion and reached Persia at an early date.

The first European distribution was overland rather than by sea, and in Gaul, England, and among the Germans, the Romans found flocks of domestic fowls well established. The first chickens to reach the New World were brought by Columbus on his second voyage in 1493. During the seventeenth and eighteenth centuries breeding stock was imported from China, England, and other countries.

The sport of cock fighting exercised a tremendous influence not only in the domestication of wild birds but also in the subsequent

distribution of the fowl. A verse written about 300 B. C. says that four things may be learned from a cock—to fight, to get up early, to eat with your family, and to protect your spouse when she gets into trouble. For centuries cock fighting has been a favorite pastime in southern and western Asia, Java, Borneo, Sumatra, and the Philippines. From India the sport was introduced into Persia and thence into Greece. Natives of Java and Sumatra have been known to stake all of their property on a cock fight, and if that was lost, they sometimes staked their wives and children.

In the United States, the real beginning of the poultry industry was contemporary with the founding of the first homes in Jamestown in 1607. In the early days poultry raising was still essentially a home enterprise, and as farming areas were opened up and homes established, farm flocks increased in numbers.

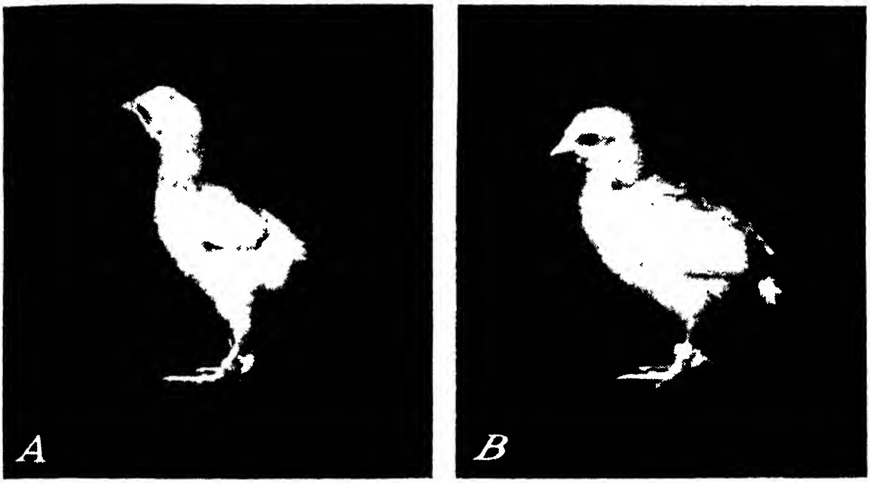


FIGURE 6.—Slow feathering is dominant to rapid feathering and is sex-linked, so that when a White Leghorn male is mated to a Jersey Black Giant female the sons are slow-feathering, as shown in *A*, and the daughters are rapid-feathering, as shown in *B*.

THE COMING OF POULTRY EXHIBITIONS

The first poultry exhibition in the United States was held in Boston in 1849. From that time onward hundreds of poultry shows have been held annually. The early exhibitions gave impetus to the growing interest in the then known breeds and varieties of fowl, for by that time several countries had each developed characteristic races. China had produced its massive breeds with feathered shanks, India its fighting cocks, Italy its small-bodied birds with nervous dispositions, England its breeds excelling in fleshing properties, and the United States the numerous breeds known in the early days.

The holding of poultry exhibitions had the effect of encouraging poultry breeders to pay considerable attention to such characteristics as type, feather contour, and color markings. In fact, so much attention was given to the perfection of characteristics of minor economic importance that vigor and qualities of greater economic importance were often sacrificed. In those days poultry breeders were occupied in evolving plumage colorations in bewildering variety, and they produced birds differing widely in body type and feather

structure, thus demonstrating the relative plasticity of the original stock. What was accomplished within recent times by breeding from selected variants is apparent from the large number of breeds and varieties of fowl that now exist. With all their beauty of form and color markings, some breeds turned out to be better than others as flesh producers and some were noted for their laying ability.

Thus over a period of several centuries man first kept chickens for sport, then for pleasure, then for utility; and breeding first concentrated on fighting qualities, then on feather form and color pattern, and finally on egg and meat production.

In the early days of American agriculture grain was cheap, and inasmuch as chickens feed largely on grains and were able to utilize much "waste," it was soon found that eggs and poultry meat could be produced quite cheaply. Eggs came to occupy a unique place in the American dietary, the demand increased, and gradually an extensive farm-poultry industry developed, along with a commercial industry of no small proportions.

FIGURE 7.—The ancestor of the domestic chicken, *Gallus bankiva*, sometimes laid two clutches of about 15 eggs each in a season. Most of its time was spent searching for food and trying to avoid predatory animals of various kinds.

Along with this development, definite attempts were gradually made to improve the quality of breeding stock from an economic standpoint. Farm-flock records were kept, selection was practiced, egg-laying contests were started, and finally record-of-performance work was undertaken. Each of these methods has its value and each has its shortcomings.

WHAT FARM-DEMONSTRATION-FLOCK RECORDS SHOW

Although, as already noted, the average egg production of the birds of the country as a whole is very low, in some States there are numerous flocks whose level of production is maintained at approximately 150 eggs per bird year after year. In a number of the States the extension poultry specialist connected with the State agricultural college arranges with a group of the more progressive farmers to keep accurate annual records of egg production and feed consumption. These flocks are called farm demonstration flocks, and the records secured from them serve a very useful purpose in impressing upon flock owners the necessity of securing a good level of egg production to make a reasonable labor income.

The females of each demonstration flock are selected at the beginning of each laying year for vigor and for external characteristics indicative of good laying ability. The males are selected for vigor and type. In some States the work has been carried on for a number of years, and it is interesting to note that during recent years the average egg production per bird has been near the 150 egg level. The data in table 2 give the records of egg production per bird during 1927 to 1933, inclusive, for five States.

WHAT most poultry breeders want to know is how to develop males and females of superior breeding worth so as to raise the level of egg production, increase the average size and improve the quality of eggs, and reduce the annual cost of flock replacements. . . . There are valid reasons why research workers should take the lead in the solution of the following vital problems, which may well be considered the heart of any program for further progress:

1. *The inheritance of egg production.*
2. *How to combine good average egg size with good production.*
3. *Whether or not it is possible to develop strains of high layers resistant to specific diseases.*
4. *How best to combine good hatchability with good production and good egg size.*
5. *Whether or not inbreeding is desirable or necessary to develop high-laying strains.*
6. *Whether or not worth-while results can be secured through cross-breeding or controlled heterozygosis.*
7. *The extent to which environment rather than inheritance is responsible for variability in breeding for such characteristics as egg production.*
8. *The best methods of selecting breeding stock and giving proper weight to production, pedigree, and progeny test.*

The data in table 2 indicate that for a period of 7 years very little, if any, progress was achieved in increasing production over the level at the beginning of the period. Moreover, since improved methods of feeding and flock management should be expected to raise the level of production over a period of years, it is quite apparent that the mass selection of breeding stock, which has been the usual practice for these flocks, is relatively ineffective in increasing egg production. As a matter of fact, no one has ever presented evidence showing

that the level of egg production is raised through the mass selection of breeding stock. In order to secure increased egg production, owners of farm demonstration flocks would be well advised to secure males for breeding purposes that are the progeny of sires and dams that have been proved to be superior in breeding worth.

FIGURE 8.—All dressed up for the fight. The proper training of fighting cocks is quite an art. Cock fighting exercised a considerable influence on the domestication of the fowl.

TABLE 2.—*The average annual egg production per bird for each of 7 consecutive years in farm-demonstration flocks in 5 States*

Year	Average annual egg production per bird					
	Indiana	Maine	Missouri	New Hampshire	Ohio	Average
1927	150	138	142	145	149	145
1928	153	142	150	155	149	150
1929	145	150	147	148	151	148
1930	152	147	145	150	149	149
1931	145	153	154	157	155	153
1932	138	161	147	157	150	151
1933	140	159	143	163	145	150

THE LAYING CONTESTS

Apparently the first organized effort to stimulate interest in the identification of superior laying stock was the holding of laying "trials" in England as early as 1897. These trials were for short periods only, but they were followed by trials of about 1 year's duration, the first of which began in 1912. From that time on an officially conducted laying competition has been held every year at the Harper-Adams Agricultural College. The first 12-month laying competi-

tion was inaugurated, however, in 1902 in New South Wales, Australia, and was held at the Hawkesbury Agricultural College. In Canada the first officially conducted laying contest was started in British Columbia in 1911, and in the United States the Storrs egg-laying contest, in Connecticut, was started in the same year. During the past decade egg-laying contests have been held in several countries and the results secured have been quite interesting.

Four things in particular have been brought forcibly to the attention of poultrymen through the results secured at the laying contests:

(1) A pen of 10 birds in a contest frequently averages over 250 eggs per bird in a year.[1]

(2) It has been shown that among 100 pens in any one contest there is usually great variation in laying ability, some pens averaging as many as 100 eggs per bird more than others.

(3) Improved methods of feeding and management, including the use of artificial lights, during recent years have resulted in securing higher average egg production records quite independent of any improvement in breeding quality that may have taken place.

(4) The most progress in breeding for increased egg production has been made with varieties such as White Leghorns, Black Langshans, Australorps, White Wyandottes, and Rhode Island Reds. In other words, in parti-colored varieties, where the poultry breeder has to select his breeding stock on the basis of perfection in color pattern in addition to egg-laying ability, an additional burden is added to the breeding program that may do much to prevent progress in dealing with characteristics of economic value.

A Comparison of Results

Since three of these egg-laying contests have been running for a considerable number of years, it is interesting to compare the results at intervals. The data are given in table 3. The records of the leading varieties only were selected. The average annual egg production per bird for a period of 3 consecutive contest years was determined; then, following an interval of several years, another average was determined for another 3 consecutive contest years. In the case of the Australian contest conducted at Hawkesbury Agricultural College, there is an interval of approximately 25 years between the two averages determined; in the case of the United States contest conducted at Storrs Agricultural College, the interval between the two averages is approximately 15 years; in the case of the English contest conducted at Harper-Adams Agricultural College, the interval between the two averages is approximately 10 years.

The data given in table 3 show that in each of the three varieties of Australian birds, there was an increase in the second 3-year average over the first 3-year average as follows: White Leghorns, 2 eggs; Black Langshan, 28 eggs; Black Orpingtons, 27 eggs. It is to be noted that the White Leghorn level of production during the first 3-year period was comparatively high—so high that after approximately 25 years the level was raised but 2 eggs per bird. Because the Black Langshan and Black Orpington level of production during the first 3-year period was lower than the White Leghorn level, greater progress was possible; during the 25-year interval the black varieties caught up to the White Leghorns.

During the first 3-year period the level of egg production of the three American varieties was comparatively low, so that in an interval of 15 years a considerable increase could be achieved in each of the three varieties. As a matter of fact, starting on a lower level than the

[1] The ancestors of the domestic fowl sometimes laid about 15 eggs in each of two clutches during the year.

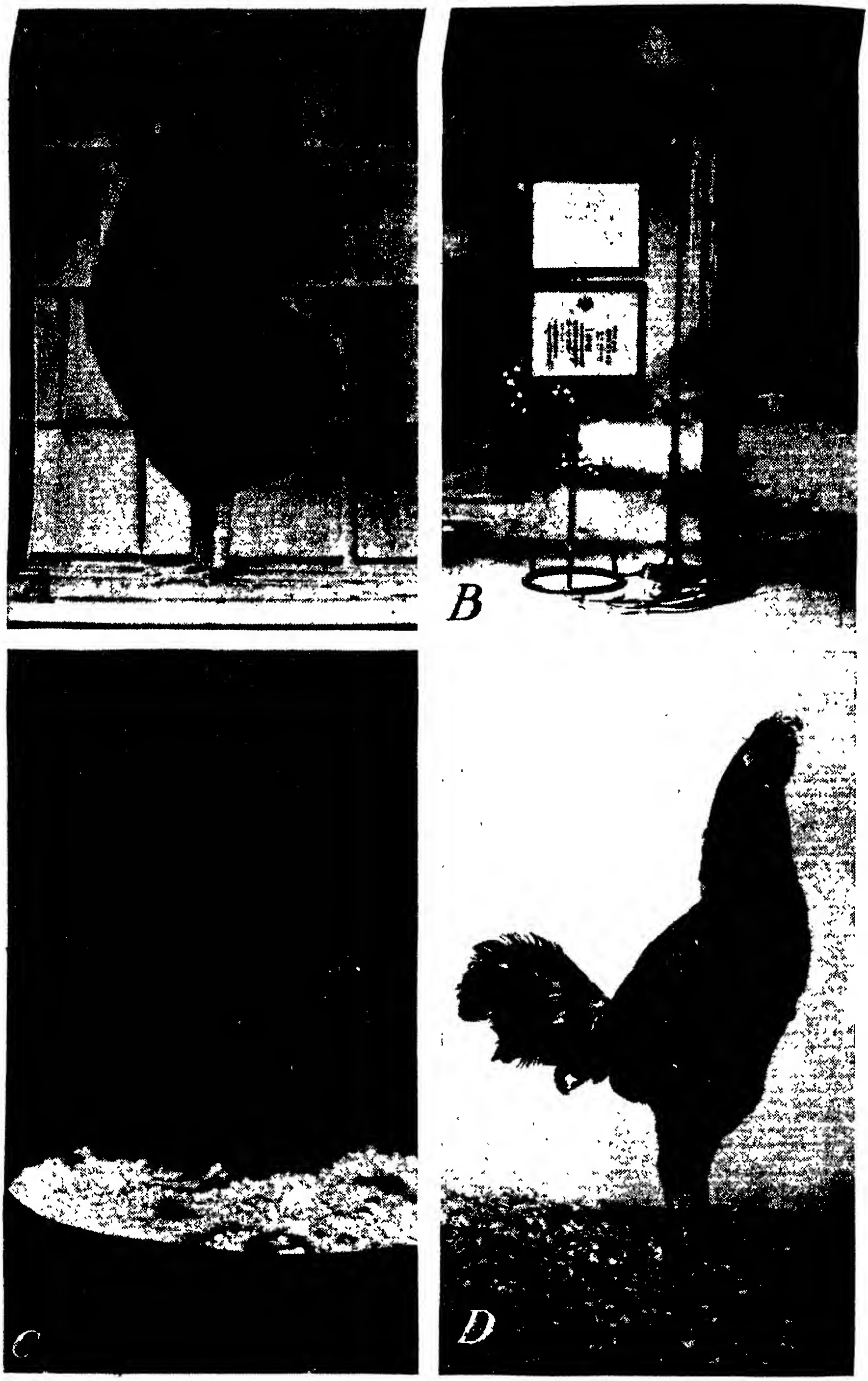


FIGURE 9.—Four interesting characteristics that show the extent to which variation has taken place among descendants of the wild fowl: *A* shows a Rumpless bird, rumplessness being dominant to the normal condition; *B* shows a Japanese Long Tailed fowl, this characteristic being incompletely dominant to normal tail; *C* shows a Creeper fowl, a characteristic which is dominant to normal and is lethal when in a homozygous condition, so that eggs containing two genes for the Creeper characteristic never hatch; *D* shows a Black Breasted Malay Game, its long legs and upstanding character being in striking contrast to the squatty appearance of the short-legged Creeper.

birds in other contests, the Storrs averages for each of the three varieties exceed by a considerable margin the averages obtained at the other two contests during the last 3-year period.

TABLE 3.—*The average annual egg production per bird for each of two 3-year periods for the leading varieties in Australian, United States, and English egg-laying contests*

Item			
	White Leghorns	Black Langshans	Black Orpingtons
Australia (Hawkesbury Agricultural College):			
3 years, 1908–11	192	171	173
3 years, 1932–35	191	199	200
	White Leghorns	Barred Plymouth Rocks	Rhode Island Reds
United States (Storrs Agricultural College):			
3 years, 1915–18	159	169	157
3 years, 1930–33	235	217	220
	White Leghorns	White Wyandottes	Light Sussex
England (Harper-Adams Agricultural College):			
3 years, 1922–25	186	186	169
3 years, 1931–34	187	192	166

William F. Kirkpatrick, in charge of the Storrs contest, has stated that during the past 5 years the average egg production of each pen of 13 birds has been determined on the records of the 10 highest ones. Since 1922 artificial lights have been used in the laying pens from 9 to 10 p. m. daily, and during the past 7 or 8 years the New England conference rations have been used, subject to slight changes from time to time. The extent to which these modifications in computation and management account for the increase in the level of egg production cannot be determined, but it may be safely assumed that during the last 15 years there has been a substantial increase in the laying ability of the birds entered in the contests.

During an interval of 10 years in the English contest, there was little change in the level of egg production of the three varieties.

It should be pointed out in connection with the results secured at egg-laying contests conducted over a period of years, that not all of the increase in egg production achieved is due to the breeding methods followed by the breeders who enter birds in the contests. Indeed, in many contests a great deal of the increase in levels of egg production has been due to improved methods of feeding and management at the contests.

Drawbacks of the Laying Contests

Another point should be noted at this time concerning the achievement of the laying contests. Although the contests have shown that relatively high average egg production is possible, the influence of the contests on poultry-breeding methods practiced by the majority of the poultry breeders has apparently been of little consequence. This is evident from the fact that, in the United States at least, the average egg production of all birds in the country has improved very little over

a long period of years. As a matter of fact there are four serious limitations in the laying contests as they have been developed.

(1) Many poultry breeders become so interested in winning first place in a contest, because of the advertising value resulting therefrom, that the use of the contests in determining the best breeding methods has been seriously neglected.

(2) The contests are so few in number in the United States that it is impossible for them to be of great service to the majority of poultry breeders.

(3) Because of the limited number of birds that can be entered by an individual poultry breeder, the amount of information gained from the birds entered is often very limited when applied to the selection of superior sires and dams in his home flock.

(4) The results secured from a few specially selected birds that are entered in a contest do not often represent the breeding worth of the flock at home.

If substantial progress in breeding for increased egg production is to be achieved among the thousands upon thousands of farm and commercial flocks that are used for breeding purposes each year, something other than laying contests must be developed.

RECORD-OF-PERFORMANCE ACCOMPLISHMENTS

The egg-laying contests served as the foundation for what is known in various countries as record-of-performance work carried on by poultry breeders on their home premises. Although the contests served the purpose of establishing official records of egg production, no provision was made for the official recognition of the hatching eggs, baby chicks, and breeding stock produced by contest birds. This is what record-of-performance work provides for, and since it is possible to include many times as many birds as could be accommodated in laying contests, it is obvious that record-of-performance work should be of far greater service to the industry than laying contests.

In the United States the record-of-performance work is sponsored by the United States Record of Performance Federation, an organization of private breeders. The work has been carried on in 17 States, and in each State it is under the supervision of an official State agency. Of the numerous minimum requirements that must be met before official recognition is given to adult stock, hatching eggs, and baby chicks, only the more important features need be given here.

It is entirely a voluntary matter whether or not a poultry breeder takes up record-of-performance work. Pullets entered in the record-of-performance project are trap-nested on the breeder's premises, and during the year an official State inspector makes at least seven unannounced inspections, trapping and weighing the birds and weighing the eggs during each inspection. The breeding pens are inspected during the hatching season, and complete records of egg production of the pullets and breeding hens, as well as incubation and hatching records, must be sent regularly to the offices of the official State agency.

In order to qualify as a record-of-performance—abbreviated to r. o. p.—female, a bird must lay 200 or more eggs averaging at least 2 ounces each in 365 days from the date of laying the first egg. R. o. p. males are the sons of r. o. p. females that were mated to an r. o. p. male whose dam laid at least 225 eggs averaging 2 ounces or more each during her first laying year. R. o. p. hatching eggs can be produced only by an r. o. p. breeding pen, and r. o. p. chicks can be produced only from r. o. p. hatching eggs. The chicks secured from each r. o. p. dam are hatched separately and banded with sealed wing bands at hatching time. Thus the sire and dam of each chick produced are known.

Progress Achieved by the R. O. P. Method

Some conception of the progress achieved by record-of-performance breeders may be gained from the data in table 4. This table gives the percentage of birds that qualified for r. o. p. out of the original number entered in record-of-performance work at the beginning of the year

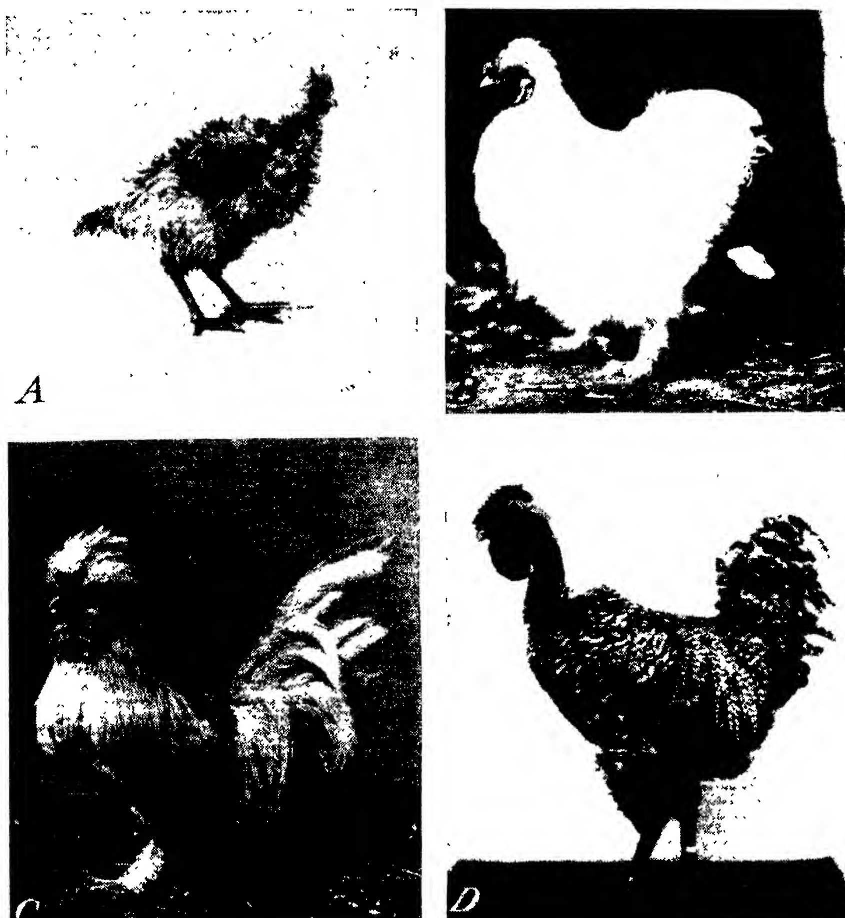


FIGURE 10.—There is great variation among domestic fowls of today in the kind and degree of plumage development. *A* shows a Frizzled fowl, frizzling being incompletely dominant to normal plumage. *B* shows a Silkie fowl, the silky condition of the plumage being due to the fact that the barbules of each feather are hookless; silky plumage is recessive to normal plumage. *C* shows a Sultan male with its crest, muff, and beard, each of the characteristics being dominant to its absence. *D* shows a Naked Neck fowl, a characteristic that has been inherited from an early strain of Transylvania fowls. In not a few cases have exploiters advertised the Naked Neck bird as the progeny of a cross between the turkey and the chicken, whereas adult birds from such a cross have never been developed insofar as is shown by accurate accounts that can be relied upon.

in each of three States. The data were obtained from three States in which a relatively large number of each of three different varieties were entered in record-of-performance work during the last 7 years.

The data in table 4 show that among the three States there are considerable differences in the percentage of birds that qualified for r. o. p. These differences may have been due to differences in the breeding worth of the sires and dams of the pullets entered in the

State record-of-performance projects. On the other hand, the differences may have been due to slightly different standards adopted for qualification, inasmuch as in some States more attention was given to standardbred quality, as distinct from production, than in other States.

TABLE 4.—*Percentage of birds in each of 3 varieties qualifying for r. o. p. in 3 States*

Year	Connecticut			Michigan			New Jersey		
	White Leghorns	Rhode Island Reds	Barred Plymouth Rocks	White Leghorns	Rhode Island Reds	Barred Plymouth Rocks	White Leghorns	Rhode Island Reds	Barred Plymouth Rocks
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1927-28	16.7	10.4	2.2	9.4	7.8	6.7	10.7	6.0	7.0
1928-29	16.9	16.2	5.8	14.1	8.2	5.1	23.1	4.7	5.3
1929-30	22.3	20.2	14.6	10.1	19.4	4.4	15.4	0.0	2.3
1930-31	20.0	17.4	19.6	16.7	16.7	8.9	12.5	1.7	3.3
1931-32	23.4	24.1	26.6	17.3	11.7	15.0	14.2	1.1	2.1
1932-33	29.3	26.6	26.9	16.7	6.0	10.9	14.5	4.0	3.2
1933-34	24.5	28.8	26.2	11.4	15.0	15.0	16.4	14.6	5.0

The most interesting observation to be noted in connection with the data in table 4 is the fact that for the most part relatively few birds qualify for r. o. p. Most of the birds fail to qualify because they do not lay 200 eggs, and some that lay 200 or more eggs fail to qualify because their eggs do not average 2 ounces in weight. Poultry breeders should realize that the smaller the percentage of birds in a flock that qualifiy, the more limited is the amount of selection possible among the qualified birds that are needed for breeding purposes. They should also realize that usually the fewer the number of breeders used and the fewer the number of matings made each year, the slower the progress to be expected in breeding for increased egg production.

Culling Pullets Lessens the Value of Results

A matter of great importance that tends to retard progress that might otherwise be achieved in record-of-performance work is the fact that many of the pullets originally entered in the project are culled before being allowed to complete their first laying year. Disease and sickness are sufficiently good reasons for some of the culling, but other pullets are culled because they start laying very late in life or lay at a very slow rate or lay very small eggs or for other reasons. Of course, a considerable amount of this culling is undoubtedly justified on purely economic grounds; the poultry breeder must make a living out of his business, and he feels justified in culling the birds that, he feels certain, have all the earmarks of uneconomical producers. At the same time, the practice of culling pullets during their first laying year tends to destroy what is known as the random sample of a population.

What all progressive poultry breeders must sooner or later realize is that the best way of determining the relative merits of the sires and dams used each year is to keep a random or representative sample of their progeny. When only selected pullets are kept, it becomes impossible to tell whether the breeding birds from which they came were really capable of producing stock of high average merit. The pullets culled out as being too poor to keep may more

nearly represent the breeding worth of their sires and dams than the pullets that were kept. This is a point that cannot be emphasized too strongly. A few prodigies of production are only "a drop in the bucket." It is the average production that must be constantly raised.

The Three-P Program—Production Record, Pedigree, and Progeny Test

A PRACTICAL breeding program intended to produce superior germ plasm, which means superior breeding stock, must rest on a three-point base: Production record, pedigree, and progeny test.

Each of these must be given due weight. At the same time, each has its pitfalls, and if the breeder does not beware of them, he will find that his results fail to come up to expectations.

At the beginning of this article, certain serious shortcomings in present scientific knowledge and experimental practice were pointed out. In spite of this, there is now a respectable body of knowledge pertinent to poultry breeding, and both experimental work and the practice of some progressive breeders throw a good deal of light on the proper use of the production record, the pedigree, and the progeny test. These points, as well as certain other aspects of poultry breeding, will now be discussed in some detail. The great need for further research and experiment is obvious; but there is also no doubt that a wider use of present knowledge would result in considerable improvement in the poultry situation as a whole.

THE VALUE AND THE DRAWBACKS OF PRODUCTION RECORDS

With a few outstanding exceptions, most of the poultry breeders in the United States apparently attach considerable significance to the first-year records of the females. Many of them seem to assume that, since a record of 200 eggs is the minimum requirement for record-of-performance qualification, all birds laying 200 or more eggs are bound to be good breeders. Moreover, there is a widespread belief that the higher the first-year record of the dam, the more eggs will her pullet progeny lay. In other words, it is claimed that the number of eggs a bird lays during her first laying year is a criterion of her breeding worth.

Data have been obtained from different sources which show that actually the first-year production record of a female is only of very limited value in predicting her breeding worth, especially when the breeding females are selected on the basis of having laid 200 or more eggs during their first laying year, as is the case in record-of-performance work in the United States. A true test of the relationship that normally exists between the egg production of dams and the egg production of their daughters could be made only in the case of dams not selected on the basis of first-year egg-production records and complete families of daughters—that is, where no culling of pullets was practiced during the first laying year. Insofar as is known, however, no such

data exist for the simple reason that in practically all projects on breeding for increased egg production, the dams are selected to a greater or less extent on the basis of their first-year records.

However, data are available which show the relationship between the egg production of selected dams and the egg production of unselected daughters, the records of all daughters except those that died being included. In table 5 are given data on Rhode Island Reds at the National Agricultural Research Center, Beltsville, Md., and on White Leghorns at the Mount Hope Farm, Williamstown, Mass., the latter having been very kindly supplied by H. D. Goodale. The Beltsville dams were selected on the basis of having laid a minimum of 200 eggs their first laying year, whereas in the case of the Mount Hope Farm dams the minimum given in table 5 is 181 eggs. Insofar as is known, except for flocks maintained at the Massachusetts Agricultural Experiment Station and at a private breeding establishment in California, the two flocks providing the data for table 5 are the only ones in the country in which all pullets that lived were allowed to complete their first year of laying, embracing 365 days from the date of the first egg in the case of each pullet.

TABLE 5.—*The average egg production of the daughters of dams classified according to the range in egg production of the dams*

Range in egg production of dams	Average egg production of daughters		Range in egg production dams	Average egg production of daughters	
	Beltsville Rhode Island Reds	Mount Hope Farm [1] White Leghorns		Beltsville Rhode Island Reds	Mount Hope Farm [1] White Leghorns
181-190		162	251-260	201	188
191-200		157	261-270	200	209
201-210	188	168	271-280	197	188
211-220	205	161	281-290	179	208
221-230	192	173	291-300		222
231-240	192	176	301-310		228
241-250	199	169	311-320		220

[1] Data from an unpublished paper given at the Poultry Science Association meeting, 1935.

The data in table 5 show no apparent relationship between the egg production of the dams and that of the daughters among the Beltsville Rhode Island Reds, but they show a slight relationship between the egg production of dams and that of the daughters among the Mount Hope Farm White Leghorns.

Relationship of Daughter and Dam Production Relatively Low

It is interesting to observe that the average egg production of the daughters of each of the first six groups of Beltsville dams was considerably higher than the average egg production of the daughters of each of the comparable groups of the Mount Hope Farm dams. The Beltsville data were obtained from matings of yearling and older hens made in 3 consecutive years, 1928 to 1930, inclusive, the dams being mated to males whose dams laid 200 or more eggs during their first laying year. The Mount Hope Farm data were obtained from pullet matings made during the years 1923 to 1929, inclusive, and Dr. Goodale has stated that the low-producing dams listed in the table

were used mainly during the first 2 or 3 years. Moreover, the sires he used each year were selected on the basis of the records of egg production made by their sisters up to February 1, from which it may be assumed that the males selected one year were somewhat superior to the males selected the preceding year. The use of sister-tested males should in itself tend to increase the egg production of the daughters raised each succeeding year, even if the dams' records of egg production had been the same for each of the 7 years.

Even so, it is apparent that the relationship between dam and daughter egg production is of a relatively low order. For instance, the group of dams with a range in production of 201–210 eggs had daughters that averaged 168 eggs, whereas the group of dams with a range in production of 271–280 eggs had daughters that averaged 188 eggs. The average egg production of these groups of dams differed

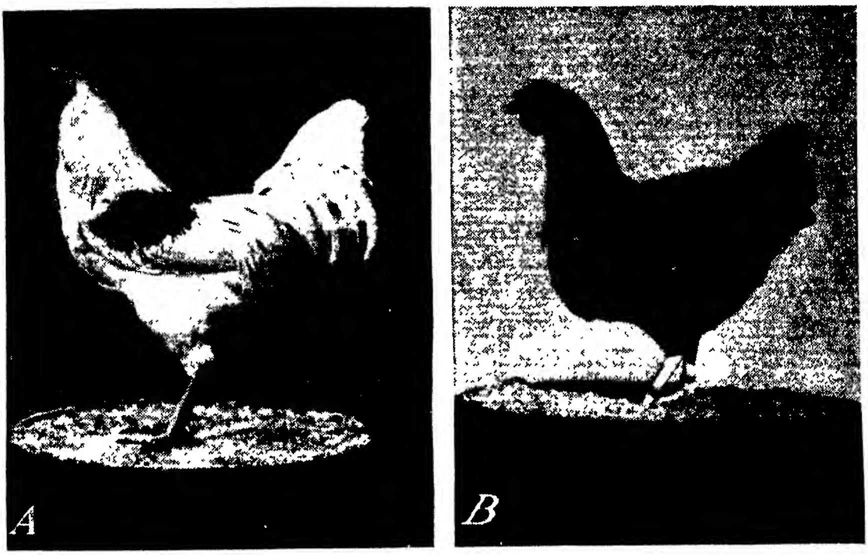


FIGURE 11.—The red-shouldered white bird (A) is the son of a White Leghorn male and a Partridge Plymouth Rock female; the white plumage of the White Leghorn is dominant to color except that it is incompletely dominant to red. The red-plumaged female (B) is the daughter of a Rhode Island Red male and a White Wyandotte female

by approximately 75 eggs, but their daughters' averages differed by only 20 eggs. The White Leghorn data show, however, that on the average the higher the egg production of the dams the higher the egg production of the daughters.

Those who hold that the egg-production record of a selected dam is an index of her breeding worth should examine carefully the source of the data on which their belief is based. In table 5 it is shown that the Mount Hope White Leghorn dams that laid from 201 to 210 eggs had daughters that averaged 168 eggs each, and the dams that laid from 281 to 290 eggs had daughters that averaged 208 eggs each, the difference in the average egg production of the two groups of daughters being 40 eggs. On the other hand, the Beltsville Rhode Island Red dams that laid from 211 to 220 eggs had daughters that averaged 205 eggs, whereas the Mount Hope White Leghorn dams that laid from 211 to 220 eggs had daughters that averaged 161 eggs, there being a difference of 44 eggs in the average production of daughters that came

from dams with the same records. The difference in the average egg production of daughters of dams with similar records was 4 eggs greater than the difference in the average egg production of daughters of dams that differed in egg production by approximately 80 eggs. Then again, those who claim that the first-year record of egg production of a bird is a good index of her breeding worth, would have great difficulty in accounting for the fact that the Beltsville dams with a range of 201–210 eggs and the Mount Hope dams with a range of 271–280 eggs produced daughters that had exactly the same average egg production.

Although the selection of dams on the basis of their first-year records of egg production is thoroughly justified, the data in table 5 show that the production records by and of themselves are of limited value. Dr. Goodale has expressed the idea very well as far as it per-

> THERE *are approximately 400,000,000 adult chickens kept annually on American farms, and they produce eggs at the rate of about 60,000 every minute, day and night. . . . It is clear, then, that egg production is a matter of great economic importance. It has been shown by surveys that the average number of eggs laid per bird per year is one of the chief factors that determine the revenue obtained from a flock. Yet average production in the country as a whole is abnormally low—approximately 80 eggs per bird per year, according to census estimates. . . . Many poultrymen fail to realize that heredity is inescapable. . . . For the poultry industry as a whole, it is of the first importance to develop strains of fowl that will produce eggs more efficiently. The cost of production and reproduction should be reduced.*

tains to the data from the Mount Hope Farm birds when he says "that on the average there is a definite relationship between the egg records of dams and those of daughters." Some poultrymen have assumed, however, that if it can be shown that in certain flocks there is a slight correlation between dam and daughter egg production, then it must follow that in all flocks the selection of breeding stock on the basis of individual records would rather quickly raise the level of egg production. These poultrymen usually overlook the conditions involved in selecting the breeding stock in those flocks where a dam-daughter correlation has been shown to exist, and they fail to realize that these conditions do not apply to the great majority of poultry breeding flocks throughout the country—including those in record-of-performance work. Most poultry breeders in the United States cull their pullet flocks rather closely and many of them use individual records of egg

production as the sole basis for selecting their breeding stock. While poultry breeders should be encouraged to select their breeding stock on the basis of production records, they should be cautioned not to attach too much significance to those records.

If the first-year egg-production records of a female served as an accurate index of her breeding worth, as some have claimed, the problem of breeding for increased egg production would be comparatively simple. The data in table 6 show how divergent are the results sometimes secured from two groups of daughters produced by the same dam mated in different years to the same or to different sires. These data were obtained from the National Agricultural Research Center, the first five dams in the table being Rhode Island Reds and the second five White Leghorns. The daughters' averages given in the table were determined for all daughters produced by each mating except for birds that died.

TABLE 6.—*The average egg production of each group of daughters of dams mated to the same and to different sires in 2 different years*

Dam no.	Sire no.—		Dam's production	Average egg production of daughters	
	First year	Second year		First year	Second year
Rhode Islands Reds:					
6024	176	176	212	217	189
6027	176	176	206	178	222
6401	334	334	233	214	184
5829	325	338	246	189	241
6142	351	368	242	182	220
White Leghorns:					
2786	50	249	257	159	228
3472	100	218	235	212	172
3728	91	248	258	213	167
3845	91	218	262	175	202
3287	100	249	230	164	225

The data in table 6 show that the same dam when mated to the same sire may produce daughters in two different years that differ in average egg production by as much as 40 eggs. When mated to different sires the daughters of the same dam in successive years differ by as much as 60 eggs.

Dr. Goodale has kindly submitted a table bearing on the very diverse results secured from dams with similar records of egg production. The data are arranged in table 7 according to the magnitude of egg production of the dams.

TABLE 7.—*The average egg production of each group of daughters of dams with similar records of egg production*

Dam no.	Dam's production	Number of daughters	Average egg production of daughters	Dam no.	Dam's production	Number of daughters	Average egg production of daughters
E 310	280	11	137	H 352	300	6	154
H 632	280	11	220	J 207	301	12	252
H 179	280	7	167	J 376	302	6	249
G 1430	282	11	201	H 679	308	16	228
G 284	284	10	255	J 938	313	6	184
G 709	286	11	167	H 119	320	15	203

Shortcomings of Individual Records

It is unfortunate for the poultry-breeding industry that many poultry breeders attach so much importance to individual records of production, especially since it has been shown that progress in breeding for increased egg production is bound to be achieved very slowly as long as a record of egg production is the only basis used in selecting the breeding stock.

There are several reasons why the record of a bird's egg production may not be nearly so significant in indicating her breeding worth as many poultry breeders are inclined to believe. Egg production is a quantitative characteristic that is easily influenced by environmental conditions and by the diet given the laying stock. Poorly balanced diets, improper methods of feeding, poor housing conditions, sudden changes in temperature, internal and external parasites, and diseases of various kinds all significantly decrease production. There may be a vast difference between the number of eggs a bird actually lays and the number she might have laid if she had been kept under ideal conditions. Rarely do ideal conditions prevail, however, that enable a bird to lay the number of eggs of which she is potentially capable.

THE IMPORTANCE OF PEDIGREE

By pedigree breeding in poultry is meant the mating of birds with pedigrees and keeping account of the parentage of the chicks produced so that their pedigrees are a matter of record. A bird's ancestry sometimes gives considerable information of value regarding its probable worth as a breeder. Of two birds with the same first-year egg-production records, the one with a good ancestry is to be preferred to the one of poor ancestry. The chances are greater that the former will give better results in breeding than the latter; the chances are greater—but there is no guarantee that a bird of good ancestry will always produce good progeny.

Although a good pedigree is of importance in selecting breeding stock, there are certain limitations in the application of pedigree selection. For instance, very little significance can be attached to individual records of egg production of ancestors beyond the third generation. Then again, the greater the variation in the environmental conditions—including diet, method of housing, and the use of artificial lights—to which a flock is subjected over a period of years, the less reliance can be placed upon the ancestors' records of production in the selection of progeny for future breeding purposes.

The data in table 8, pertaining to Beltsville Rhode Island Reds and Mount Hope Farm White Leghorns, show that the higher the egg production of the three nearest female ancestors of both sire and dam, the higher is likely to be the average egg production of their progeny. In the case of each flock, the environmental conditions were kept as uniform as possible from year to year.

Judging from the data in table 8, it is apparent that the selection of breeding stock on the basis of ancestors' records of production to the third generation is of considerable importance. As a matter of fact, the more information there is in the pedigree concerning the records of egg production of the sisters of parents and grandparents, and the more information there is concerning the breeding performance of parents and grandparents and their relatives, the greater the value of the pedigree in selecting breeding stock.

TABLE 8.—*The average egg production of daughters according to the range in average egg production of the three nearest female ancestors of both sire and dam*

Range in average egg production of the three nearest female ancestors of both sire and dam	Average egg production of daughters		Range in average egg production of the three nearest female ancestors of both sire and dam	Average egg production of daughters	
	Beltsville Rhode Island Reds	Mount Hope Farm White Leghorns [1]		Beltsville Rhode Island Reds	Mount Hope Farm White Leghorns [1]
209-217	186		254-262		199
218-226	197	180	263-271		213
227-235	199	166	272-280		216
236-244	205	176	281-289		222
245-253		208	290-298		210

[1] Data from an unpublished paper given at the Poultry Science Association meeting, 1935.

THE SIGNIFICANCE OF PROGENY TESTING

The supreme test of the worth of a bird as a breeder is the kind of progeny it produces. Thus in the case of a dam it is not her individual laying record that counts so much as the average laying record of her daughters, which is quite a different thing. Strangely enough, the first impetus given to progeny testing in breeding for increased egg production was the failure resulting from an attempt to develop an egg-laying strain through the selection of female breeders based entirely on their first-year records of egg production. Apparently, the first attempt at a State institution to improve egg production through selection was made by the late G. M. Gowell of the Maine Agricultural Experiment Station. Gowell's work was carried on some 35 years ago with Barred Plymouth Rocks, and the records show that over a period of 9 years the practice of selecting female breeders on the basis of their first-year trap-nest records failed to produce an increase in the level of egg production among the pullets raised each year.

The work of Gowell, however, laid the foundation for later work which demonstrated the significance of the progeny test in breeding for increased egg production. Continuing the breeding work with the Barred Plymouth Rock at the Maine Station, Raymond Pearl demonstrated that by selecting cockerels and pullets for future breeding purposes each year from among the best families of that year, a steady increase in the level of egg production was achieved. Cockerels and pullets to be used as breeders were selected from among the progeny of sires and dams that proved to be superior in breeding worth to other sires and dams. The progeny-test method of selecting breeding stock has been used consistently for a period of years in the breeding of Rhode Island Reds at the Massachusetts Agricultural Experiment Station, where F. A. Hays has achieved outstanding results.

It is particularly important for poultry breeders to be able to identify sires of superior breeding worth because the average sire has about 10 times as many chicks as the average dam. A practical way of applying the progeny test to sires without trap-nesting either the dams or their daughters has been suggested by A. L. Hagedoorn of the Netherlands. Separate breeding pens are maintained in each of which one male is mated to the usual quota of females. The chicks from each sire are banded at hatching time so that the pullets can be distinguished from the pullets secured from other sires. The laying pullets from each sire are placed in separate houses or pens.

and by comparing the average egg production of the pullets of each sire, the breeder is able to determine which sires were superior in breeding worth.

The difference in breeding worth of sires mated to trap-nested Rhode Island Red dams having minimum first-year records of 200 eggs and White Leghorn dams having minimum first-year records of 225 eggs is shown in table 9. The data were obtained from a few of the matings made at the National Agricultural Research Center. The records of egg production of all daughters placed in the laying houses, except for birds that died, were used to compute the average for each of the different groups of daughters. The mortality among Rhode Island Red daughters was 9.17 and among the White Leghorns 13.26 percent. The average egg production of all the Rhode Island Red daughters was 192.03 and of all the White Leghorn daughters 192.85.

Table 9.—*Average egg production of daughters of different Rhode Island Red sires mated to Rhode Island Red dams that laid 200 or more eggs, and of different White Leghorn sires mated to White Leghorn dams that laid 225 eggs or more*

Sire no.	Rhode Island Reds			Sire no.	White Leghorns		
	Average egg production of sire's mates	Number of daughters	Average egg production of daughters		Average egg production of sire's mates	Number of daughters	Average egg production of daughters
173	223	48	219	3	248	45	229
10105	242	49	216	250	243	37	227
[1] 334	231	37	211	249	243	71	206
[1] 338	238	31	206	252	247	48	200
[1] 334	242	32	205	91	254	46	199
[1] 330	246	46	201	100	248	59	193
[1] 330	250	38	195	259	243	69	185
200	243	52	193	254	237	51	179
[1] 338	250	60	192	10106	239	46	179
351	232	75	171	50	228	49	168

[1] These sires were used in 2 consecutive breeding seasons.

The data in table 9 make it quite clear that certain sires were much superior to others from the standpoint of transmitting laying ability to their daughters. The sons and daughters of sires nos. 173 and 3 are likely to be much better breeders than the sons and daughters of sires nos. 351 and 50.

Random Versus Selective Sampling

It has been pointed out previously that the cooperative survey on plant and animal improvement revealed the fact that comparatively few poultry breeders keep sufficiently complete records to make possible an analysis of their results. The fact was also brought out that in many cases rather rigid culling of the pullet flocks is practiced each year, so that a random sample of the progeny population is not retained for the purpose of identifying the superior sires and dams.

On the other hand, there are some poultry breeders who carry on progeny-testing work on an extensive scale and who, from the various matings made, retain either all of the progeny or a sufficiently large number to make it possible to concentrate breeding work among families that have been developed from superior sires and dams. The record made of a random sample of the progeny, of course, gives the

most accurate index of the breeding worth of the breeder's flock or mating. For instance, a poultry breeder in Idaho sold one of his customers 400 White Leghorn chicks, and the 197 pullets that were raised averaged approximately 238 eggs per bird.

As compared with the other classes of domestic livestock, so many more matings can be made and so many more offspring can be produced in 1 year by even a few breeders of chickens that it would be practically impossible to encompass within the space allotted to this article the results secured from any but a small proportion of the more outstanding matings. An enumeration of the outstanding matings made by the leading poultry breeders during the past 2 or 3 years would make a very formidable list. Moreover, except for certain details, the various matings tell the same story. Rather than give the results of a large number of matings, it was deemed advisable to give a few illustrations of the results secured by a few of the leading

FIGURE 12.—The best index of the breeding worth of a dam is the kind of progeny she produces. The White Leghorn (*A*) laid 290 eggs and had seven daughters that laid an average of 230 each. The Rhode Island Red (*B*) laid 236 eggs and had five daughters that laid an average of 226 each.

poultry breeders. The results these men have obtained show what is possible in a well-planned breeding program involving progeny testing and the use of sires and dams that have proved to be of superior breeding worth. For this purpose, the data submitted by the following breeders are presented here: A, Washington, White Leghorns; B, Connecticut, Barred Plymouth Rocks; C, California, White Leghorns; D, Massachusetts, White Leghorns and Rhode Island Reds; and E, Massachusetts, Rhode Island Reds.

The data in table 10 give the average egg production of the daughters of different sires used by the poultry breeders mentioned.

Owing to the fact that some culling of the daughters of certain sires was practiced during the first laying year, as indicated in table 10, it is not possible to ascertain a true measure of the breeding worth of the sires in these cases. At the same time, even in these cases most of the sires had a sufficiently large number of daughters with a high average egg production to justify the poultry breeders in regarding these sires as of superior breeding worth.

Table 10.—*The average egg production of daughters of different sires used in a few private breeding flocks*

Poultry breeder	Variety	Sire no.	Average egg production of sire's mates	Number of daughters	Average egg production of daughters
A	White Leghorns	28	261	56	[1] 235
		116 [2]	263	208	[1] 242
		165 [2]	284	81	[1] 238
		194	278	40	[1] 250
		336 [2]	287	191	[1] 236
		354	276	45	[1] 241
		468 [2]	264	145	[1] 235
B	Barred Plymouth Rocks	1 [2]	253	128	[1] 193
		541 [2]	253	77	[1] 216
		D27	197	22	[1] 187
C	White Leghorns	G10	264	76	219
		G8	276	84	218
		G4	262	80	209
		G7	261	135	208
		G6	276	108	191
		G2	274	105	166
		G11	285	114	163
D	White Leghorns	1	283	130	243
		2	289	39	240
		3	259	55	228
		4	273	18	169
		5	255	33	152
	Rhode Island Reds	1	252	57	242
		2	277	104	235
		3	268	26	234
		4	237	39	168
		5	270	28	165
E	Rhode Island Reds	14-4839	260	40	[2] 248
		11-2	232	24	[2] 240
		11-2A	232	19	[2] 229
		11-3	210	44	[2] 236
		13	257	32	[2] 255

[1] In these groups of daughters, culling during the first laying year was practiced to some extent.
[2] These sires were used for 2 or more breeding seasons.

Identifying Superior Sires and Dams

Particular mention should be made of the data submitted by C and D. When the questionnaires were sent to a number of leading poultry breeders, they were asked to give the results of some outstanding sires and the results of some inferior sires. Both of the poultrymen mentioned were good enough to include data on inferior sires as well as superior ones. Since neither of these poultrymen culled pullets during the first laying year, it is possible to make fairly accurate appraisal of the breeding worth of the different sires involved.

C, for instance, knows full well that sire no. G10, whose mates' average was 264 eggs and daughters' average was 219 eggs, is greatly superior in breeding worth to sire no. G11, whose mates' average was 285 eggs and daughters' average was 163 eggs. Likewise, D, with his White Leghorns, would pick sire no. 1, whose mates and daughters averaged 283 and 243 eggs, respectively, over sire no. 5, whose mates and daughters averaged 255 and 152, respectively. D's Rhode Island Red sire no. 1 was mated to females that averaged 252 eggs and his daughters averaged 242 eggs whereas sire no. 5, although mated to females that averaged 270 eggs, had daughters that averaged only 165 eggs.

Although it has been pointed out previously that the ability to identify and make use of sires of superior breeding worth is of paramount importance in raising the level of egg production of the flocks of the country, nevertheless it is highly important to be able to identify a female of superior breeding worth, if for no other reason than

to produce more superior males. Some of the poultry breeders submitted data giving the average egg production of the daughters of a few of the dams they have used. The data of A and B, given in table 11, for White Leghorns and Barred Plymouth Rocks, respectively, are sufficient to show what can be accomplished.

TABLE 11.—*The average egg production of daughters of different dams of outstanding breeding worth as reported in a survey of poultry breeding*

Breeder and variety	Dam no.	Dam's production	Number of daughters	Average egg production of daughters	Breeder and variety	Dam no.	Dam's production	Number of daughters	Average egg production of daughters
A, White Leghorns	[1] Y 308	299	23	243	B, Barred Plymouth Rocks	K33916	312	19	203
	[1] Y 417	260	39	253		3232	258	8	223
	[1] Y 1095	273	39	246		3392	254	8	234
	[1] A 2711	278	42	234		3846	215	18	215
	[1] A 3131	267	25	248		981	296	7	201
	[1] B 268	276	27	238		984	214	8	228
	O 401	275	15	255		994	234	11	186
	G 2235	281	8	278		2731	280	11	251
	P 262	284	5	269		3779	224	10	216
	P 2494	270	9	252					
	[1] G 712	314	28	230					

[1] These birds were used 2 or more years.

Even though some of the daughters of the different White Leghorn dams listed in table 11 were culled during their first laying year, it is apparent that all of the dams are birds of considerable merit as determined by the progeny test. There was practically no culling in the case of the Barred Plymouth Rock groups of daughters.

It might be well to mention here that the most progressive breeders use every means available to identify superior sires and dams in their flocks. Among other things, in addition to the kind of progeny produced by different sires and dams, the production records of their sisters are usually taken into consideration. For instance, A's White Leghorn dam no. A2711 had 11 sisters that averaged 240 eggs; dam no. A3131 had 12 sisters that averaged 256 eggs; dam no. G2235 had 12 sisters that averaged 255 eggs; dam no. P262 had 10 sisters that averaged 240 eggs. B's Barred Plymouth Rock dam no. 3232 had 18 sisters that averaged 200 eggs and dam no. 3779 had 12 sisters that averaged 219 eggs.

Then again, many poultry breeders give considerable weight to pedigree in selecting their breeding stock. Such breeders should always remember, however, that certain things which the breeder may practice tend to lessen the value of the pedigree. As already pointed out, the greater the extent to which the diet and environmental factors governing egg production have been changed from year to year, the less significant are the records of egg production of the birds appearing in the pedigree of an individual. Again, it should always be kept in mind that the greater the extent to which culling was practiced in previous years, the less the value of the records of the birds that were retained and that appear in the pedigree.

It is apparent, therefore, that even under the best of circumstances there are a number of handicaps, to say nothing of the expense involved, under which the average poultry breeder must labor in his

efforts to select sires and dams of superior breeding worth. Then again, since the chicken is a relatively short-lived creature and since sires and dams may be 3 or 4 years old by the time they have been proved to be of superior breeding worth by the progeny test, it is apparent that if their "blood" is to be perpetuated, their sons and daughters must be used for future breeding purposes. The use of these sons and daughters is sound breeding practice because they have a far greater chance of being superior breeders than the sons and daughters of unproved sires and dams.

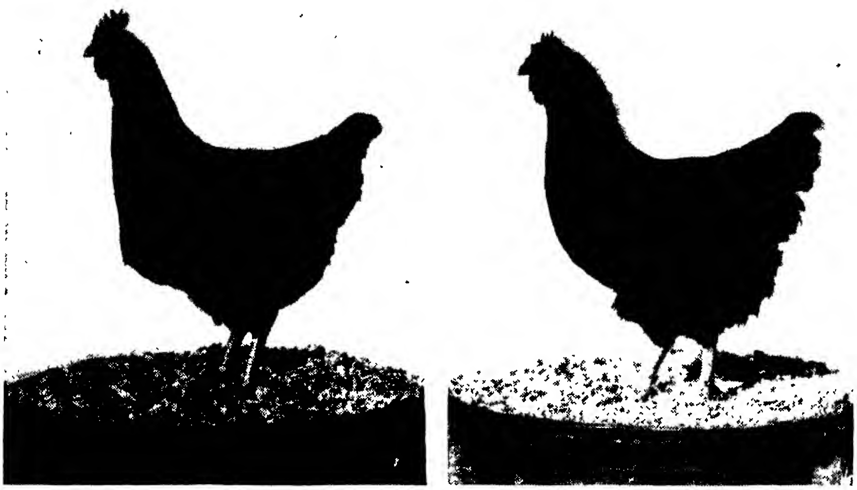


FIGURE 13.—It is from dams of superior breeding worth that superior males are obtained. The Rhode Island Red hen (*A*) laid 259 eggs and had 7 daughters that laid an average of 208 each. The Rhode Island Red hen (*B*) laid 248 eggs and had 10 daughters that laid an average of 245 each. It is from such families of sisters whose average egg production is high that good breeding brothers are to be obtained.

It Is the Family That Counts

The following examples will serve to emphasize the importance of selecting for breeding purposes males and females that are members of good families. At the National Agricultural Research Center three Rhode Island Red sires, nos. 330, 334, and 338, gave such satisfactory results in their first breeding season that they were used a second season. No culling was practiced among the daughters during their first laying year. The average egg production of the daughters produced each of the 2 years has already been given in table 9, but for the sake of convenience to the reader they are repeated here: Sire no. 330: First group of daughters, 201 eggs; second group, 195 eggs. Sire no. 334: First group of daughters, 211 eggs; second group, 205 eggs. Sire no. 338: First group of daughters, 206 eggs; second group, 192 eggs.

Sires nos. 330 and 334 were half brothers on their sire's side. The dam of no. 330 was one of the eight sisters that averaged 213 eggs, and no. 330 had five sisters that averaged 236 eggs. The dam of no. 334 was one of four sisters that averaged 222 eggs, and no. 334 had four sisters that averaged 214 eggs. The dam of no. 338 was one of two sisters that averaged 225 eggs, and no. 338 had 16 sisters that

averaged 235 eggs. A son of no. 334 produced 58 daughters that averaged 205 eggs. This son had six sisters that averaged 214 eggs.

The intelligent selection of breeding stock on a family basis, which is the essence of progeny testing, is the surest way of making progress.

Some Main Objectives and Methods in Poultry Breeding

IT IS all too true that many poultry breeders have been carrying on their breeding operations for years without having the slightest knowledge of the various egg-production characteristics their birds possess. On the other hand, the more progressive breeders, by their system of carefully tabulated records for individual birds and for the results secured from various matings, are well fortified with specific information that makes possible intelligent selection of males and females for future breeding.

CHARACTERISTICS DETERMINING EGG PRODUCTION

Poultry breeders have found that the observations made in the breeding of Rhode Island Reds during the last 30 years at the Massachusetts Agricultural Experiment Station have been of great help in deciding which birds to select as breeders. For a number of years the work at the Massachusetts station was under the direction of Dr. Goodale, who was followed by F. A. Hays. The station has made important contributions to the knowledge of the mode of inheritance of various characteristics of economic importance in poultry. Among other things, it has been observed that there are five principal characteristics that determine the number of eggs a bird lays during her first laying year.

Briefly, in order to lay well a pullet should possess the five following characteristics: (1) Early sexual maturity; (2) good rate of laying; (3) non broodiness; (4) absence of winter pause; and (5) persistence of production.

Numerous poultry breeders and workers at some of the State experiment stations take these five characteristics into consideration in the selection of layers to be used as future breeders. An analysis of the egg-production records of Rhode Island Reds and White Leghorns at the National Agricultural Research Center shows, however, that in these flocks winter pause has not been of great importance.

By sexual maturity is meant the age of the bird in days at the time she begins laying. Rate of laying is determined by figuring, on a percentage basis, the number of eggs laid from the date of the first egg to a given date in relation to the total number of days involved; or rate may be determined on the basis of average size of the winter clutch, as Hays has done. A clutch is the number of eggs laid during successive days without any intervening days of no production. Broodiness is a simple characteristic to determine; the number of times a pullet goes broody and the length of time are usually taken into consideration, or the percentage of birds in the flock that go broody is considered. Persistence of production simply means that

the pullet continues laying well toward the close of her first laying year, which is 365 days from the date of the first egg. In the case of the Beltsville flocks, persistence of production was determined by the number of eggs laid during August and September. In the case of the Massachusetts flocks, persistence was determined on the basis of the length of time laying continued from the date of the first egg.

If a White Leghorn or Rhode Island Red pullet is to lay approximately 200 eggs during her first laying year, the White Leghorn should commence laying at about 180 days of age and the Rhode Island Red at about 190 days. Pullets of both breeds should lay at about the rate of 60 percent. There should be practically no broodiness. They should lay approximately 25 eggs during August and September.

Each of these characteristics can be developed in a flock by the adoption of a sound breeding program. The results obtained with the Massachusetts Rhode Island Reds show what can be accomplished. The data given in table 12 were kindly supplied by Dr. Hays.

Table 12.—*Increase in level of egg production with improvement in four characteristics in Rhode Island Reds at the Massachusetts Agricultural Experiment Station*

Year	Pullets	Sexual maturity	Rate of laying [1]	Non-broodiness	Persistence	Average egg production
	Number	*Days*		*Percent*	*Days*	
1920	162	200	2.7	54	331	200
1921	440	211	3.3	55	304	198
1922	565	197	2.7	71	322	200
1923	472	209	2.4	73	323	189
1924	422	196	2.5	67	327	196
1925	553	192	3.1	58	330	205
1926	479	199	2.7	81	331	205
1927	551	185	3.5	90	321	197
1928	560	196	3.4	72	335	215
1929	507	197	3.1	87	330	208
1930	461	191	3.7	78	340	214
1931	462	189	3.8	84	344	234
1932	377	202	3.3	88	338	222
1933	501	194	3.3	95	342	214

[1] Average number of eggs per clutch.

Since many poultrymen who keep Plymouth Rocks, Rhode Island Reds, Wyandottes, and similar breeds often experience difficulty in eliminating broodiness from their flocks, it is interesting to note that the number of birds in a flock that go broody, as well as the length of time they spend in being broody, can be materially reduced if every time a hen goes broody she is banded with a celluloid band and is never used as a breeder. The economic importance of reducing broodiness is shown by the difference in egg production between Beltsville Rhode Island Reds that went broody and those that showed no broodiness. The birds that went broody once or oftener during the year averaged 180 eggs, while those that did not go broody averaged 205 eggs.

BREEDING FOR EGG QUALITY

Egg production is not the only criterion for determining the breeding worth of sires and dams. There are four other characteristics, of interest to consumers as well as producers, that should be taken into consideration in the development of breeding stock that will best

meet the needs of the poultry industry. Housewives want eggs for cooking and baking purposes that have the following four qualities: (1) Good size, (2) uniform shell color, (3) sound shell texture, and (4) good interior quality.

These are the four characteristics that poultry breeders should attempt to develop in their breeding stock. They are all transmitted by inheritance. It is true, of course, that very little is known concerning the exact manner in which these characteristics are inherited, but it has been established that the proper selection of breeding stock will soon lead to considerable improvement. The method of selecting for each of the four characteristics is exactly the same as outlined for improving egg production. For each characteristic the poultry breeder should select birds for breeding purposes on the basis of the kind of eggs laid by each individual, the kind of eggs laid by the ancestors, and the kind of eggs laid by the progeny. In other words, selection is based on production, pedigree, and progeny test.

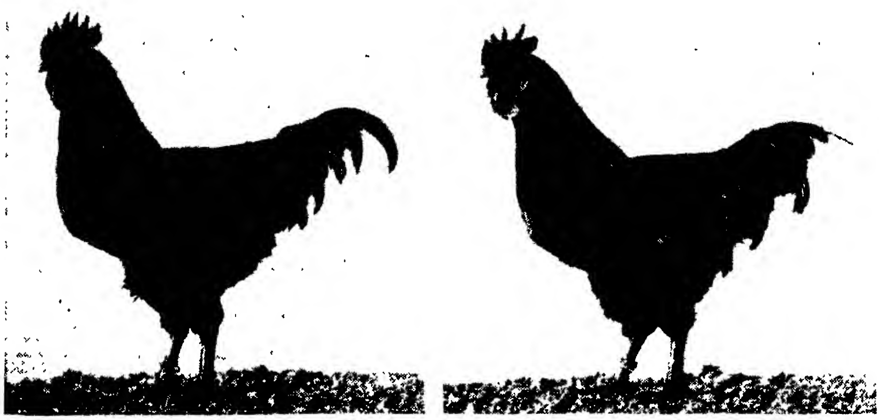


FIGURE 14.—The progeny test tells the tale. Here are two brother Rhode Island Reds that produced entirely different results when mated to dams with similar records of egg production. The daughters of the sire (left) laid an average of 160 eggs each, while the daughters of the sire (right) laid an average of 206 each. Here is a case where the egg-production record of the sires' dam and the pedigree were of no avail in determining the difference in their breeding worth. The sons and daughters of the superior sire are likely in turn to be much better breeders than the sons and daughters of the inferior sire If practical poultry breeders are to make the most progress in breeding for increased egg production, they must select their breeding stock on the basis of what the progeny test reveals.

Since this method of selection has already been discussed at some length with respect to the development of high-laying strains, it is not necessary to go into details again. There are certain things, however, that it would be well to emphasize and that every poultry breeder should always keep in mind in his regular breeding practice.

There is a tendency for body size to be associated with egg size; that is, in any given flock the largest birds usually lay the largest eggs. Most poultry breeders and flock owners could do quite a bit toward increasing the average size of eggs laid by the flock as a whole by culling out the smallest birds every year. Among the birds that are left, those that lay very small eggs should be culled rather than used in the breeding pen. This is quite important because it has been found that pullets that lay very small eggs at commencement of laying are very likely to lay small eggs for the rest of the year.

Also, it has been found that in many cases the heavier producers in a high-laying strain lay smaller eggs than the average producers.

This is not to say that high production and good egg size cannot be combined in the same bird, for this has been accomplished a thousand times over by poultry breeders. The point is that more rigid selection of the breeding stock must be practiced because two characteristics instead of one are involved.

One of the most important things to keep in mind in developing a strain noted for good egg size is to select males as breeders that are the sons of dams that lay a good-sized egg. The market standard is a 2-ounce egg, and that is why females qualifying for record of performance are required to lay 200 eggs or more averaging at least 2 ounces in weight. Since a record-of-performance male can be secured only from a record-of-performance female, it is obvious that the program should do much toward improving egg size in the flocks of the country through the widespread distribution of record-of-performance males for breeding purposes.

The problem of securing uniformity of shell color is of greater importance in White Leghorns and other "white egg" breeds than in "brown egg" breeds. The average housewife has less objection to varying shades of brown in a dozen brown eggs than to a few tinted eggs in a dozen white ones. In some flocks of white-egg breeds quite a few of the birds may lay tinted eggs. By trap-nesting, these offenders can be identified and eliminated from the flock. But that is not enough; the poultry breeder should go through his records and identify the sire and dam of the pullets laying the tinted eggs, and not only remove the sire and dam from the breeding pen but avoid using any of their progeny as breeders. This is just one example of applying the progeny test in changing the breeding qualities of a strain of fowls.

Very little is known concerning the inheritance of shell texture, and for the most part, providing the diet is satisfactory, most flocks lay eggs that are reasonably sound in that respect. In case a number of birds in a flock are found to produce eggs with thin shells, resulting in excessive breakage, offenders should be located, and they, and all closely related birds likely to transmit the defect, should be removed from the flock.

During the last 5 years more attention has been given to interior egg quality than during the previous 25 years. This is because many housewives have become more discriminating about the color of yolk and the quality of white or albumen. Color of yolk is controlled more by feeding than by breeding, but the percentage of thick white is apparently inherited. At any rate, H. J. Almquist and L. W. Taylor at the California Agricultural Experiment Station, and C. W. Knox and A. B. Godfrey at the National Agricultural Research Center, have shown that in the flocks they studied, individuals differed in the percentage of the thick white of their eggs. The results obtained indicate that by proper selection a strain of fowls could be developed that would lay eggs having a high percentage of thick white.

INHERITANCE OF REPRODUCTIVE ABILITY

In addition to breeding for production and quality of eggs, the poultry breeder is naturally interested in doing everything possible to reduce the cost of replacing his flock from year to year. Surveys conducted

in different parts of the country on the economics of egg production have shown that for the most efficient production of eggs, the flock should be comprised of approximately one-third yearling hens and two-thirds pullets. This means that about two-thirds of the flock must be replaced every year.

In order to reduce the annual cost of replacements, the poultryman must secure good fertility and good hatchability, and there must be low pullet mortality, which means that there must be resistance to disease. A well-rounded breeding program must take these three characteristics into consideration because of their great practical importance in the development of strains that reproduce themselves most efficiently.

There is little specific evidence bearing on the inheritance of fertility, although in one or two cases results have been secured which indicate that fertility is an inherited characteristic. Low fertility may be due to a variety of causes, some of which have nothing to do with heredity. For instance, a male may refuse to mate with one or more of his consorts but may mate several times daily with certain other consorts. Such a case is known as preferential mating and although it is a matter of common occurrence, it can usually be remedied by replacing the unmated females with others. Sometimes lack of fertility is due to the physical inability of a male and a female to copulate, as in the case of birds with extremely short backs. Severely cold weather tends to lower fertility and too many males or too few males in a flock will also result in lowering fertility.

Occasionally a male may be sterile, that is, his germ cells may be incapable of fertilizing female cells. Likewise, some females are sterile or nearly so. Then again, there may be physiological incompatibility between male and female cells of certain males and females so that fertility is abnormally low.

In the average flock, however, the problem of securing good fertility seems to be largely one of proper management of the breeding stock. It is obviously of great importance to secure good fertility from a male that has proved to be of superior breeding worth. Moreover, if such a male could be mated to 50 or 100 hens instead of approximately 15, as is usually the case, much more rapid improvement would be possible. Quite recently, J. P. Quinn and W. H. Burrows, at the National Agricultural Research Center, have demonstrated that it is possible to secure good fertility from hens artificially inseminated with semen secured from male birds by manipulation. This discovery makes possible the mating of a large number of hens to one male. If a certain male was the son of a good producer, had an excellent pedigree, and by the progeny test proved to be of superior breeding worth, and if he could subsequently become a sire of several hundred superior progeny, he would indeed be a benefactor to the poultry industry.

Hatchability is an inherited characteristic, and improvement can be secured through adopting proper methods of selection. The same principles of selection apply as in breeding for other characteristics. A hatch of 65 percent of all eggs set, or 75 percent of the fertile eggs laid by a dam, is a good standard for the selection of sires and dams that should be retained for further breeding purposes, and particular attention should be paid to the selection of cockerels for breeding that are the sons of dams having high hatchability.

SELECTION FOR FLESH PRODUCTION

Although the main objective of most poultry breeders is to develop increased egg-laying ability in their flocks, nevertheless, fleshing properties are of considerable economic importance, especially in the case of such breeds as Orpingtons, Plymouth Rocks, Rhode Island Reds, and Wyandottes. Good body type and size are desirable in order that the largest possible amount of meat may be produced by any surplus cockerels that are sold as broilers or roasters, and by any hens that are sold for market after serving their purpose as egg producers.

N. F. Waters, formerly at the Rhode Island Experiment Station, secured results from crosses between Light Brahmas and White Leghorns that showed that the inheritance of body size is a very complex problem. Black Rose Comb bantams and Barred Plymouth Rocks were crossed at the National Agricultural Research Center, the results secured indicating that a large number of genes are involved in the inheritance of body size.

Even though comparatively little is known concerning the inheritance of body size, poultry breeders are wise in culling out, as most of them do, all small-sized cockerels and pullets in the fall of the year. This is important even in Leghorns. In addition, adult birds that do not attain a satisfactory weight for the breed should be culled before the breeding pens are made up.

It is particularly important to cull out all birds that grow at a slow rate, especially those that are inclined to have bare backs or are otherwise poorly feathered during the growing period.

HEREDITY OF DISEASE RESISTANCE

Perhaps the besetting sin of the poultry industry is the high mortality that occurs in the country's crop of pullets produced each year. In many flocks of pullets, a mortality of 30 or 40 percent is not uncommon. What is worse, during the past few years losses seem to have been on the increase. This has taken place in spite of the long-standing urge to breed for vigor, in spite of the various State sanitation campaigns for waging war on worms and for growing healthy pullets, and in spite of the vast amount of research conducted on numerous poultry diseases.

The results of three lines of research work indicate that perhaps it may be possible by breeding to develop strains of fowls resistant to infectious disease. At the Illinois Agricultural Experiment Station, E. Roberts and L. E. Card found that chicks from certain hens were much more resistant to infection by the organism causing pullorum disease than were chicks from other hens. The results secured led them to believe that it may be possible to develop strains of domestic fowl highly resistant to pullorum disease. At the Iowa Agricultural Experiment Station, W. V. Lambert, and C. W. Knox demonstrated that four generations of selection combined with some inbreeding resulted in a marked increase in the resistance of their birds to fowl typhoid. At the University of British Columbia a group of workers observed marked differences in the resistance of different strains to fowl paralysis. The results secured from these experiments with pullorum disease, fowl typhoid, and fowl paralysis are encouraging and suggest the need for much more work on similar lines. Studies

on the inheritance of infectious diseases are problems for public institutions, however, rather than for the practical poultry breeder.

On the other hand, certain results have been obtained from breeding methods practiced by poultry breeders that suggest that pullet mortality can be reduced. From a variety of sources it has been determined that mortality among the pullet progeny of pullet breeders is frequently greater than among the pullet progeny of hen breeders. Undoubtedly too many poultrymen use as breeders some immature pullets and others lacking in vigor which because of mortality or selection would not get into the hen breeding pen. It is obvious that families showing a high incidence of mortality from a particular disease should be discarded and their progeny should not be used as breeders.

INBREEDING, OUTBREEDING, AND CROSS-BREEDING

Having taken the proper steps in the selection of the breeding stock by considering production records, pedigree, and the results secured from progeny testing, the next step for the poultry breeder to determine is whether he shall practice inbreeding, outbreeding, or cross-breeding in making his matings.

Inbreeding is the mating of relatives; and since there are degrees of relationship, such as brothers and sisters, uncles and nieces, and cousins, so there are degrees of inbreeding. The poultry breeder who starts with a breeding flock of 50 birds and does not introduce any birds from outside sources for a period of years is bound to practice a considerable amount of inbreeding as time goes on.

The closest form of inbreeding is the mating of brother and sister, and the next closest form is either the mating of father and daughter or son and mother. Many poultry breeders are often in a quandary as to how closely they should practice inbreeding for the purpose of retaining the desirable characteristics which some of their breeding stock have been shown to possess. The question in the mind of the average breeder is whether or not inbreeding will tend to develop heavy laying as a fixed characteristic in his flock.

Unfortunately, there is very little evidence bearing on the effects of close inbreeding on egg production, although several breeders have tried it at different times and have secured variable results. Most of the experiments in close inbreeding have been made to study its effects on hatchability of eggs and variability of progeny. From these studies it has been concluded in general that hatchability tends to decrease and embryo and chick mortality tends to increase with inbreeding.

L. J. Cole and J. G. Halpin of the Wisconsin Agricultural Experiment Station inbred brother and sister Rhode Island Reds for 4 years and observed a marked decline in vigor to such an extent that in the fourth year hatchability was so low the experiment had to be discontinued. Another inbreeding experiment started subsequently produced similar results.

The results secured at the Connecticut and Massachusetts Agricultural Experiment Stations by L. C. Dunn and F. A. Hays, respectively, at the National Poultry Institute of England by J. C. Dunkerly, and at the National Agricultural Research Center, Beltsville, show that close inbreeding brings a decrease in egg production. It has been shown, however, that close inbreeding is not so harmful in some

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strains of birds as in others. Moreover, less intense forms of inbreeding should prove advantageous in many cases.

Inbreeding is not injurious merely by reason of the close relationship of the individuals that are mated. The only injury resulting from inbreeding comes from the inheritance received. If undesirable characteristics become manifest in the inbred birds, it is only because these undesirable characteristics existed in the original stock, where they were able to persist for generations under the protection of more favorable characteristics.

A poultry breeder with a flock of good stock might wisely mate closely related individuals occasionally. At the same time, the closer the degree of inbreeding practiced in any flock, the more rigid should be the selection of the progeny, and consequently the greater the number of individuals necessary from which to select future breeders.

Among the various ways in which inbreeding can be carried on almost indefinitely, especially if a relatively large number of matings are made every year, is to use one individual or his or her progeny repeatedly in the breeding project. This form of inbreeding is popularly referred to as line breeding. Matings are made up each year in such a way that a superior male or female or their progeny is mated to unrelated stock and to a few distantly related birds, thus perpetuating the desirable qualities of the superior birds and avoiding the possible ill effects that may result from too close inbreeding.

There is another sense, however, in which inbreeding is highly important. It is the quickest method by which characteristics, good or bad, can be isolated, made homozygous in a strain, and studied accurately from the standpoint of inheritance. Thus it becomes a powerful means for bringing out desired traits. If these are found to be combined with undesirable traits in the inbred strain, the latter may be subordinated by well-controlled crossing. This method is extensively used in plant breeding; indeed, it is responsible for most of the valuable achievements in cross-fertilized crops in recent times. In animal breeding, it must be considered as still an experimental technique too costly and perhaps too difficult for use except in research work. The full possibilities of this technique in poultry breeding are yet to be explored.

Many poultry breeders are so strongly prejudiced against practicing inbreeding to any extent that they make a point of securing breeding stock of the same breed or variety, but unrelated to their own, from some other poultry breeder. This is popularly called outbreeding. The results obtained from outbreeding are sometimes satisfactory and sometimes very unsatisfactory; it all depends on the qualities possessed by the two strains of the same variety that are crossed and how these strains "nick," as old-time breeders would say. J. Holmes Martin at the Kentucky Experiment Station has carried on some outbreeding work which demonstrates this point. A poultry breeder who has a well-bred flock should try a few experimental matings before venturing on a wholesale program of crossing all of his breeding stock with birds of another strain.

Cross-breeding, or mating two different breeds or varieties, is sometimes practiced with a view to combining the desirable qualities of each. Broiler producers resort to cross-breeding quite extensively because it has been found that cross-bred chicks usually grow faster, especially during the first 10 or 12 weeks, than purebred chicks of

the parental breeds that are crossed. Research work at the Maine and Kansas Agricultural Experiment Stations by Raymond Pearl and D. C. Warren, respectively, have shown that cross-breeding generally tends to increase hatchability and decrease chick mortality. In other words, hybrid vigor is involved. On the other hand, research work at the National Agricultural Research Center has shown that if two strains having low hatchability are crossed, hatchability is usually increased, whereas if two strains having high hatchability are crossed it is not increased. Cross-breeding usually results in more broodiness in the progeny.

At the Kansas Station Warren crossed White Leghorns with Rhode Island Reds and White Leghorns with Jersey Black Giants and observed that for the most part the cross-bred birds laid better than the purebred birds. During recent years the sale of cross-bred chicks from commercial hatcheries has apparently been on the increase, but poultrymen who purchase them should always keep in mind that the results in egg production secured from the cross-bred pullets are determined by the quality of the parental stocks that are crossed. Generally speaking the mating of high-producing females of one breed to males of a low-producing breed should not be expected to produce cross-bred pullets that will lay as well as their high-producing purebred dams. On the other hand, the crossing of two highly developed laying strains may be very much worth while.

Warren crossed high-production strains of White Leghorns from Kansas and from the Pacific coast. The stimulation from crossing was not as apparent as when breeds were crossed, but the females showed better egg production and hatchability than either of the parent strains. However, chick mortality and weight at 8 weeks were not improved.

A Plan for the National Distribution of Superior Breeding Stock

IN SPITE of the many unsolved problems and the lack of much information of a fundamental nature concerning the art of poultry breeding, it is cheering to report that the poultry industry has taken steps to distribute the "blood" of such superior breeding stock as is being produced. Going on the theory that it is worth while to make the best of what we have, representatives of the industry in the United States have organized a voluntary National Poultry Improvement Plan. This is a plan that has very great significance. If it works out well, it should not only result in improving the existing situation; it should mean that any real results of research in the future could be put to practical use in the industry as a whole with a minimum of delay.

In each State the regulations of the improvement plan are under the supervision of an official State agency. This represents the poultry interests of the State and also an official body such as the college of agriculture or the State department of agriculture or both.

The United States Department of Agriculture has been cooperati with the States in putting the plan into effect, beginning in July 19 on a uniform basis among the States.

The plan provides for official recognition of various classes of breeding stock, hatching eggs, and baby chicks produced by poultry breeders, and various classes of chicks distributed from hatcheries. The hatcheries occupy a unique place in the poultry industry because they can do a great deal of good by distributing chicks of superior

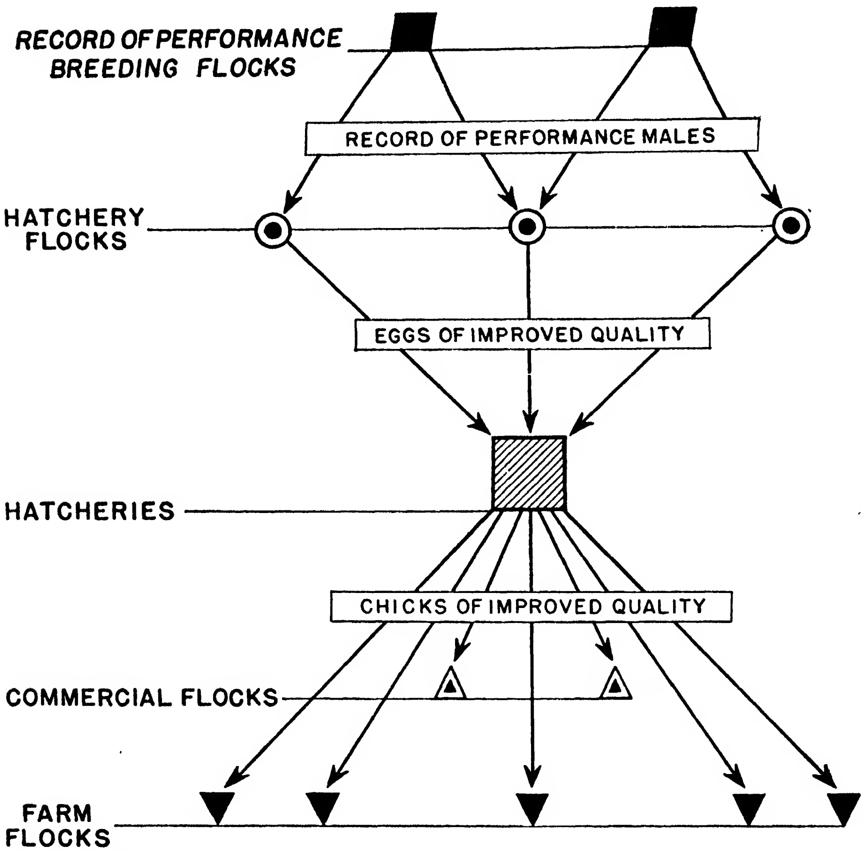

FIGURE 15.—A scheme showing in a general way how the breeding stock produced by record-of-performance breeders are used to raise the level of egg production of the flocks of the country.

quality, or they can do a great deal of harm if only a few of them distribute chicks of inferior quality. There are approximately 12,000 hatcheries in the country and they have an egg capacity at one setting of approximately 300,000,000 eggs. If all of them operated at full capacity during the normal hatching season they would produce practically as many chicks as are raised annually in the United States, that is, over 750,000,000. It is obvious, therefore, that the hatcheries are important in any plan for the improvement of the farm and commercial flocks of the country.

The flocks used to produce the different classes of eggs provided for in the plan must be carefully selected by a representative of the

official State agency, and provision is made for their subsequent inspection by an official State inspector. The females of each flock are carefully selected for vigor and characteristics indicating laying ability and the males are rigidly selected for vigor and qualities indicating good breeding. Flocks used to produce certain classes of eggs must be mated to males produced by record-of-performance breeders.

Official recognition is given to females that lay a minimum of 200 eggs during the first laying year, providing the eggs weigh on the average 2 ounces each. Record-of-performance males can only be secured from record-of-performance matings. One of the best features of the improvement plan provides for the official recognition of sires and dams that prove to be of superior breeding worth as determined by the progeny test.

Hatching eggs used to produce each of the different classes of chicks provided for in the plan must each weigh a certain minimum amount and they must be uniform in shape and sound in shell texture, and in the case of the "white-egg" breeds the eggs must be free of tints. The egg-weight requirements of the plan are very important because in too many cases hatchery operators are inclined to set undersized eggs, which usually hatch into undersized chicks.

Another most important feature of the improvement plan provides for the official recognition of flocks that have been tested for pullorum disease and have had all reactors removed. The testing work must be done by properly qualified persons using one of three different specified methods of testing. Widespread testing and removal of all reactors should result in great benefit to the poultry industry because the organism causing the disease is transmitted from the infected dam to her chicks through the medium of the egg, and flocks of chicks highly infected usually suffer heavy mortality.

Very briefly, the improvement plan provides for the distribution of superior breeding stock produced by poultry breeders who carry on record-of-performance work. This superior breeding stock is sent to owners of flocks that supply eggs to hatcheries. The hatcheries in turn distribute chicks to farm and commercial flock owners. Thus the influence of superior breeding stock is carried right through to the farm and commercial flocks kept for egg production. There is no doubt that the level of egg production of the flocks of the country can be increased considerably by more widespread distribution of sires and dams of superior breeding worth. The poultry-improvement plan will succeed to the extent that poultry breeders and hatchery operators appreciate the possibilities that lie ahead and fulfill the obligations resting upon them.

THE RESPONSIBILITY OF THE POULTRY BREEDER

A portion of this article has dealt with the need of superior breeding stock in order to make farm and commercial poultry production more efficient and more profitable. Most of the previous discussion has had to do with the various factors involved in identifying superior breeding birds and ways and means of increasing their numbers. It need only be pointed out here that the desired objectives will not be gained, however, unless poultry breeders appreciate their responsibility.

It may be taken for granted that, for the most part, superior breeding stock can be developed only by a class of superior poultry breeders. In fact, the greatest need of the poultry industry is greatly increased numbers of poultry breeders who not only know how to raise and manage chickens properly but who have a sound knowledge of the more fundamental problems involved in the selection and mating of breeding stock. Superior breeding stock can be developed only through the adoption of a sound breeding program.

It must be a balanced program, combining high egg production, good rate of growth, good body size for the breed, efficient flesh production, eggs of good size and desirable interior quality, good fertility and hatchability, and low chick and pullet mortality. To accomplish these things with any degree of success is a formidable task. Since inheritance plays such an important role in the development of these numerous characteristics, it becomes apparent that numerous matings are necessary and the largest possible number of progeny should be kept to provide for the wisest selection of the most superior sons and daughters of the most superior sires and dams.

Poultry breeders must learn that the best breeders cannot be selected from their external appearance alone; it is the genes that count. For instance, the White Leghorn has white plumage because it carries a gene that prohibits the development of pigment. But the White Leghorn also carries the sex-linked gene for barring, as certain crosses have demonstrated. Now the average White Leghorn breeder would not suspect the presence of the sex-linked gene for barring in his stock, but it is there just the same. Then again, the White Plymouth Rock carries a gene for the extension of black pigment to all parts of its plumage, but the bird is white because it lacks a certain gene for the production of pigment. And so it is with many breeds and varieties; there is "more than meets the eye." Likewise with stock that is being bred for such characteristics as egg production, egg weight, and low mortality. Breeding tests tell the tale.

The poultry breeder should know how to measure the results he secures. Of course, he knows how to count and weigh eggs and weigh birds, but he must be able to do much more than that in order to make the most progress. It is the average results that are secured from large families obtained from each mating that serve as the best measure in selecting superior sires and dams. Moreover, the breeding stock and their progeny should be kept under as uniform conditions as possible from year to year.

The production record, the pedigree, and the progeny test provide three means of identifying the dam of superior breeding worth. A superior sire is identified by the production record of his dam, his own pedigree, the average egg production of his full sisters, and the kind of progeny he produces. It can be said with a reasonable degree of certainty that in the present state of the poultry breeding industry of the United States, the selection of breeding stock on the basis of the progeny test is the most important step in the development of a balanced breeding program.

Future progress in poultry-breeding work will depend on the kind of poultry breeders that carry on the work. The chicken presents the possibilities; upon the poultry breeders rest the responsibilities.

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Appendix

Experiment Station Research Workers in the United States Who Have Carried on Poultry-Breeding Research Work

California: L. W. Taylor, University of California, Berkeley; V. S. Asmundson, Experiment Station, Davis.
Connecticut: Walter Landauer, genetics, State College, Storrs.
Illinois: Elmer Roberts, animal genetics, University of Illinois, Urbana.
Iowa: W. V. Lambert, genetics, Iowa State College, Ames; N. F. Waters, animal husbandry, Iowa State College, Ames.
Kansas: D. C. Warren, Kansas State College, Manhattan.
Kentucky: J. Holmes Martin, University of Kentucky, Lexington.
Louisiana: C. P. Upp, Louisiana State University, Baton Rouge.
Maine: W. F. Dove, biology, University of Maine, Orono.
Massachusetts: F. A. Hays, Massachusetts State College, Amherst.
New York: F. B. Hutt and G. O. Hall, Cornell University, Ithaca.
Oklahoma: R. G. Jaap, poultry husbandry, Agricultural College, Stillwater.
Wisconsin: L. J. Cole, genetics, Agricultural College, Madison.

Experiment Station Personnel Supervising Poultry-Breeding Projects

Alabama: D. F. King.
Arizona: H. Embleton, H. B. Hinds.
California: P. W. Gregory, H. J. Almquist.
Idaho: C. E. Lampman.
Illinois: L. E. Card.
Indiana: R. E. Roberts.
Mississippi: G. R. Sipe.
Missouri: E. M. Funk.
New Hampshire: T. B. Charles.
New Jersey: W. C. Thompson, C. S. Platt.
New Mexico: L. N. Berry.
North Carolina: C. H. Bostian, R. S. Dearstyne.
Oklahoma: R. B. Thompson, L. Morris, R. Penquite.
Oregon: F. L. Knowlton.
Pennsylvania: D. R. Marble, E. W. Callenbach.
Texas: C. B. Godbey, R. M. Sherwood.
Utah: B. Alder.
Washington: M. W. Miller, G. E. Bearse.
West Virginia: T. B. Clark.
Wisconsin: J. G. Halpin, G. E. Annin.

Poultry-Breeding Research Workers at Other Institutions

California: C. H. Danforth, Stanford University.
Illinois: L. V. Domm, University of Chicago.
Massachusetts: H. D. Goodale, Mount Hope Farm, Williamstown.
New York: L. C. Dunn, Columbia University, New York City.

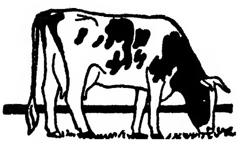
Poultry-Breeding Research Workers in the United States Department of Agriculture

Morley A. Jull, National Agricultural Research Center, Beltsville, Md.
Charles W. Knox, National Agricultural Research Center, Beltsville, Md.
Joseph P. Quinn, National Agricultural Research Center, Beltsville, Md.
Albert B. Godfrey, National Agricultural Research Center, Beltsville, Md.
Marlow W. Olsen, National Agricultural Research Center, Beltsville, Md.

Research Workers Who Have Made Outstanding Contributions in Poultry-Breeding Work But Not Now Actively Engaged Therein

California: T. H. Morgan, California Institute of Technology, Pasadena.
Maryland: Raymond Pearl, Johns Hopkins University, Baltimore.
New York: C. B. Davenport, Carnegie Institute of Washington, Cold Spring Harbor New York.

Superior Germ Plasm in Dairy Herds



By R. R. Graves, Principal Specialist in Dairy Cattle Breeding, and M. H. Fohrman, Senior Dairy Husbandman,[1] *Division of Dairy Cattle Breeding, Feeding, and Management, Bureau of Dairy Industry*

WITH more than 26 million dairy cows spread over the entire United States, a survey of herds for superior germ plasm is a tremendous undertaking. How the survey which is the subject of this article was conducted among agricultural experiment stations and the owners of more than a thousand commercial herds is described in later pages. It is sufficient at this point to say that no similar project on so large a scale had previously been attempted in this country. Hitherto the genetic study of dairy cattle has been restricted for the most part to analysis of the hereditary make-up of the individual sire or dam. Some attempts have been made in studies in the Bureau of Dairy Industry, and more recently by the Holstein-Friesian Association, to show the inheritance for production being built in some herds through the use of a number of sires. To analyze all the sires used in herds during the entire period of record keeping, however, and to show the female lines of descent and their relationship to the various sires in a large number of herds, is pioneer work in the field of animal breeding.

In the present state of genetic knowledge relating to livestock, many might call it premature to attempt a survey of progress in breeding superior germ plasm in dairy-cattle herds in which records of production have been kept over a period of years. The effort is necessarily based on the generally accepted theory that butterfat and milk production are characters inherited through quantitative factors (genes) and that on the average sires proved for ability to increase daughters' records over dams' records carry superior germ plasm and should be used in herd improvement. Neither the actual genes nor their mode of inheritance is known, though presumably there are many of them and they interact with one another in an extremely complex way. It may be pointed out, however, that this

[1] Other members of this Division who have assisted with the preparation of the material are W. W. Swett, T. E. Woodward, J. R. Dawson, J. B. Shepherd, C. A. Matthews, and C. J. Stauber.

basic assumption is not essentially different from that continually used in practical plant breeding. The wheat or the corn breeder knows neither the genes that influence production nor their mode of inheritance, but by assuming that they exist and that his general theory of their operation is not too far from the truth, he is able to get results of unquestionable value.

The prematurity in this case, then, does not lie in the nature of the assumption, but in applying it to an animal organism and using it on a wide scale to draw practical conclusions as to intrinsic worth—that is, to compare and grade breeding merit on the basis of the three characteristics of primary economic importance in dairy cattle: milk production, butterfat production, and butterfat percentage. These quantitative elements can be measured for individual animals and entire herds, and a practical procedure has been in use long enough to yield many data useful in the selection of sires possessing superior inheritance for high levels of production. Nevertheless there are recognized shortcomings and difficulties in the methods employed.

Material on type of animals was included in the survey for the benefit of those who lay stress on conformation, and who feel that this may have some connection with productive ability. This material is available to the breeders concerned and the present plan is to publish it elsewhere than in this Yearbook.

It is recognized that by no means all of the superior germ plasm in dairy cattle in the United States is included in the present survey. There is undoubtedly a great deal of it in herds for which records of production have not been kept, as well as in those for which record keeping has been intermittent or selective. In fact many of the best known breeding herds fall in the latter class and were therefore not available for use in the survey. Moreover, in many States limitations of time and available funds did not permit the inclusion even of all the herds in which records had been kept for a considerable time.

The present survey, then, cannot be considered as a completed structure. It is ground work for the building of a more enlightened and constructive breeding program.

Organized record keeping for dairy cattle has never attained desirable momentum and volume, though it has been advocated for many years by educational organizations and institutions. Those who keep records have used them principally for culling their low-producing cows. It has been estimated that in our dairy herd-improvement associations only about one-third of the cows produce enough to be profitable to their owners, another third just about break even, and the last third are such low producers as to lose money each year for their owners. In considering this statement it should be remembered that less than 2 percent of the total dairy-cow population are being tested through herd-improvement associations and that this 2 percent, together with the cattle being tested through breed organizations, are in all probability considerably higher producing animals on the average than the remainder of the dairy-cow population

In the lack of a constructive breeding program that will produce a general improvement in germ plasm for higher producing levels, dairy farmers will continue to be burdened with a large percentage of cows that lack the inherent ability to produce sufficient milk and butterfat to render them profitable. Culling out a few low-producing cows is not a corrective for this situation. The poor cows will always

be in the herds to cull unless the owners follow a breeding program that will eliminate the germ plasm responsible for low production.

This survey, then, shows what has actually been happening under the present system of breeding in the better herds. It offers the first picture, though an incomplete one, of the results of the testing program. The picture is incomplete because only the best results are shown.

Without doubt critical consideration will bring flaws to light in the present survey, and many improvements and refinements should be possible in the future. This criticism is invited and will be welcomed. It has not even been possible to develop all the conclusions that might be drawn from the survey. The mere analysis of thousands of survey cards, the calculations involved, and the summarizing and boiling down of details took weeks of work on the part of a large staff. The development of additional material is a task that will take some time after the present Yearbook is published. In many States, those who have made the survey and obtained the data from the farms see so much value in this new field of work that they are asking how it can be continued; how it may be placed on a permanent basis.

The Origin and Background of the Present Breeds of Dairy Cattle

THE links that indicate the line of descent of our domestic cattle from their wild forebears are skeletons and parts of skeletons excavated from various geological strata, lake beds, and marshes where they resisted decay to be resurrected later for painstaking study by archeologists, paleontologists, and osteologists, who forged the bony chain of evolution. Their conclusions in turn were strengthened by gleanings from the drawings left by primitive man.

Disregarding some confusion in early terminology and some persisting disagreement, it is evident that our domesticated cattle came from the wild species of the genus *Bos*, which is the largest genus of the family Bovidae. The wild cattle are long since extinct, but the long-horned species, *B. primigenius*, survived in the wild state in Europe up to the beginning of the fifteenth century (*2*).[2] It is believed that this was probably a variety of *B. namadicus*, the Asiatic wild ox. Its place in the ancestry of domestic cattle appears to be well established.

Some confusion persists regarding the origin of the short-horned breeds. A small wild species called *B. longifrons* is suggested as the ancestor of these cattle, but according to one hypothesis, *B. longifrons*—also called *B. brachyceros*—was a stunted type of *B. namadicus*. If this is true it would indicate a common origin for all domestic European breeds, although most writers believe that they came from two or more sources. The controversy may be cleared up when more bones have been unearthed.

In any event, there were wild cattle in abundance when primitive man decided to add herding to hunting in order to safeguard and supplement his food supply. Presumably domestication of cattle

[2] Italic numbers in parentheses refer to Literature Cited, p. 1069.

started with the capture and taming of young animals. Historians believe the formation of domestic flocks and herds began about 10,000 years ago, perhaps in Asia. Migrations and conquests brought about a mixing and blending of these early stocks.

Since there was much roaming about in search of new pastures and more or less constant warfare between neighboring tribes, it is safe to assume that no thought was given to improvement of flocks and herds during the ages preceding the dawn of civilization. Early historians recount the accomplishments of kings, emperors, and nobles in the field of animal husbandry, but many of these chroniclers flattered their patrons. Livestock breeding for these men may have been more a vanity than a vocation.

During the Middle Ages, war, the great ravisher and destroyer, held back progress. Men were needed to fight battles, and pastoral pursuits were often neglected. With greater security, however, improvement was possible. Envy may have been the first compelling motive in livestock improvement. It operated long before the lure of profit and the pressure of economic necessity began to stimulate breed betterment.

One of the early results of breeding under domestication was the appearance and fixing of variations, particularly in coat colors and also in size, shape of horns, and other easily identified characteristics. These early differentiations, encouraged by selection, marked the beginning of the breaking up of the general domesticated stock into distinct breeds. Intermingling of these strains from time to time brought about new combinations and later additional segregations. Race consciousness and hostility often assisted in the establishment and fixing of breed characteristics.

The history of the major dairy-cattle breeds should begin with their origin. By deduction it is fairly well established that Holsteins sprang from *Bos primigenius;* Ayrshires from the same source, crossed with *B. longifrons;* and Jerseys, Guernseys, and Brown Swiss cattle from *B. longifrons.* ug oi

Following the origination of a breed ther(,eriod of unrecorded development until some of the breettle .racteristics are fixed and there are enough animals to attract attention and bring breed recognition. Recorded history, however, actually begins only with the opening of a studbook.

EARLY IMPORTATIONS AND THE FOUNDING OF BREED ASSOCIATIONS IN THE UNITED STATES

Cattle came to North America with the first settlers. They were maintained throughout the colonial period, but there is no record of the development of a distinct American dairy breed. Lack of a ready market or better opportunities in other fields may have retarded the development of the dairy industry. When conditions were more favorable, foreign dairy breeds were established and the logical procedure was to import animals of these breeds. In the meantime, livestock breeding in England had been stimulated by the work of Bakewell, the Collings brothers, Bates, and other pioneers.

The history of the development of breeds of cattle abroad differs from that in the United States. In most cases in other countries the herdbooks remained open for a time at least to all animals that met certain requirements as to breed characteristics. This tended to

broaden the base of the breed by the admission of animals other than those already registered. It appears that the normal procedure in founding a herdbook here was to register all animals for which proof of importation could be presented, to admit their known progeny to registry, and thereafter to limit entry to descendants of registered animals and those subsequently imported from the source of the breed. Early records show that Jerseys imported 15 years before the founding of the American Jersey Cattle Club were registered. After registration abroad was well established, then foreign registry was required for entry of imported cattle in the breed herdbooks here.

Dates claimed for early importations lose significance because there was no authentic record that would even permit breed identification before the registration books were set up. The terms Alderney, Jersey, and Guernsey were more or less synonymous in the early cattle literature. Most of the first Channel Island cattle came to this country by way of England. In 1817, 1840, and 1850 Jersey cattle are said to have been imported to the United States. More came in 1868, the year in which the American Jersey Cattle Club was formed. From that time on there has been a fairly steady flow of cattle from the island of Jersey, but the great increase in numbers is due to the expanding activities of American breeders.

Mention is made by historians of large black and white cattle imported in 1795, and it is reasonable to assume that the Dutch settlers in New York would, from time to time, have brought in some of the dairy animals from their native land. Two registry associations were organized in 1871 and 1879, and these were consolidated in 1885 to form the Holstein-Friesian Association of America. The cattle eligible to registry were those of black and white color already registered in the Holstein, Dutch-Friesian, Holstein-Friesian, and Western Holstein-Friesian herdbooks, their direct descendants, and imported animals or their descendants registered in the Netherlands, Friesian, or North Holland herdbooks. Importations were numerous from 1875 to 1885 but only a few more came in early in the twentieth century. Then high registry fees and quarantine practically ended importations.

Ayrshires gained recognition as a breed in the county of Ayr in Scotland. Scottish settlers brought them to Canada in the early nineteenth century, and 1822 and 1837 are mentioned as dates of early importations to Connecticut and Massachusetts. Animals have been brought in from Scotland at intervals up to the present, but quarantines have frequently interrupted the movement. The Ayrshire Breeders' Association was organized in 1875 and the following year published the first volume of the Aryshire Record, which was a continuation of the American and Canadian Ayrshire Herd Record. This first volume carried the statement that every animal would be registered on the merits of its pedigree, without regard to any previous record. The animals recorded include those tracing directly to importation and others believed to be purebred.

Registered Guernsey cattle in this country today are those imported in recent years or descendants of earlier importations from the islands of Guernsey, Alderney, Sark, and Herm, in the English Channel, where animals were recorded in the herdbook of the Royal Guernsey Agricultural Society, which began in 1879. Hill (*3*) gives 1830 or 1831 as the date of the first importation of Guernsey cattle to the United States. The descendants of these animals were later

recorded in the herdbook of the American Guernsey Cattle Club, which was founded in 1877. Other importations are reported in 1840, 1858, and 1868. Guernsey cattle have continued to come into this country in varying numbers since the club was founded.

Brown Swiss cattle, as the name indicates, originated in Switzerland. They have been imported only in limited numbers, and the first importations date back to 1869 and 1882. In 1880 the Brown Swiss Breeders' Association was established, and registration and the issuance of herdbooks have been carried on by the organization since that date.

Major breed associations have been in existence here for 50 years or more, and the consequent development of a common interest has resulted in efforts to encourage breed promotion and expansion. Competitive showing was one of the first means of breed advertising and continues to be important. Disregarding the indifference of breeders toward the inclusion of production standards as a joint basis for awards in the show ring, dairy-cattle shows at least helped to acquaint the public with the external characteristics of the different breeds and afforded direct contact with prospective buyers. As time went on the showing of dairy cattle became professionalized, and the competition narrowed down to those herds whose owners were able to purchase prospective winners at long prices and hire skilled showmen to fit and pose their animals before the judges. Inability to match this type of showing has driven most of the smaller herd owners out of the field, and during recent years the general public has evinced a noticeably waning interest in cattle shows. This may help to bring about reforms designed to recapture interest.

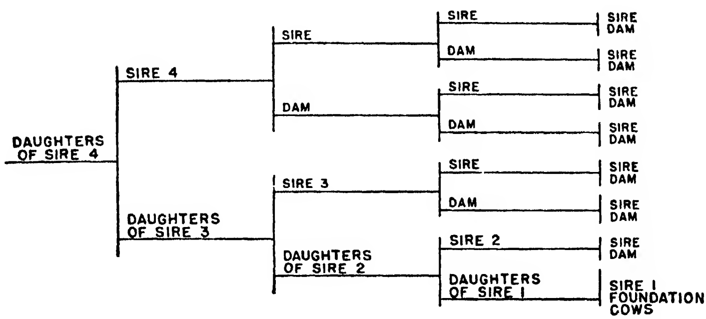
FIRST RECORDS OF PRODUCTION AND THE BEGINNING OF OFFICIAL TESTING

Fortunately, the commercial value of the dairy cow can be determined early in her productive life. Breeders individually initiated practices for measuring producing ability by weighing the milk and by churning the milk and weighing the butter for a given period. These early efforts were the beginnings of the present official tests, herd tests, and dairy herd-improvement tests. In 1884 a volume entitled "Butter Tests of Jerseys" was published as a continuation of a previous list published in 1882 of all churn tests of registered Jerseys that had produced 14 or more pounds of churned butter in 7 consecutive days. About 450 records were listed. Some date back to 1879 and give evidence of an early interest in the ability of cows to produce. Determination of yearly production by the churn test was a tedious and expensive procedure, but in 1877 a record of 705 pounds of churned butter was reported for Jersey Belle of Scituate, and in the next dozen years several records made in this way exceeded that of Jersey Belle.

The early importers and handlers of Holsteins were quick to realize the advantage their cattle had in quantity production. The first full yearly record was reported in 1870 as 12,681 pounds, made by the cow Dowager. Five years later 16,274 pounds of milk was the top, and in another 5 years the record had reached 18,000. Records were broken in rapid succession until 30,318 pounds was reported for Pietertje 2d in 1888. In the eighties Holstein breeders began to make short-time butter records. In 1891 Pauline Paul completed

a year's production with 1,154 pounds of butter. Most of the early public competitions in butter production were between Holsteins and Jerseys.

THE RIGHT KIND OF HERD PEDIGREE



THE producing ability of the daughters of Sire 4, which may typify the last generation in any herd where 4 successive sires have been used, as illustrated in the above chart, is determined for the most part by the kind of germ plasm possessed by the sires that are numbered 4, 3, 2, and 1.

The producing ability carried by the germ plasm of these sires can be measured by the performance of their offspring.

If the germ plasm of each of these four sires was definitely superior as proved by adequate and unselected data, then the cows of the present generation will be superior.

Each sire received a certain inheritance from his parents at the time of his conception. Nothing in his later life can change this inheritance. And his ancestors can be forgotten when he himself has been definitely proved by his progeny.

The important thing with this last generation of cows is that each individual animal be backed by a number of direct generations of breeding that has been proved superior, namely, the paternal sire, and through the maternal side, in each generation the superior germ plasm should come through the daughter of a sire that was proved superior.

In Hill's book (3) there is a list of 165 weekly butter records of 14 pounds of butter or more made by Guernsey cows. The author states that many of these were butterfat records with 20 percent

added for overrun, and that they were made after 1870. A yearly milk record of 12,856 pounds was completed in 1889 by the Guernsey cow Lily Alexandre. Several large Guernsey herd owners kept private yearly production records for their cows before the establishment of the Advanced Register.

All of these early efforts indicate appreciation of the record of performance as a valuable means of breed promotion and advertising. As competition grew and more herd owners engaged in record keeping, there developed a need for providing unbiased supervision for the tests. Fortunately, Dr. Babcock had perfected his butterfat test in 1890, and repeated trials had proved it to be an ideal means for determining the butterfat content of milk. Its use, together with the weighing of the milk, made the determination of production a simpler procedure. The convenience of the Babcock test and the need for disinterested supervision led to the establishment of authenticated testing.

The Advanced Registry of Holstein Cattle was established at the time of the consolidation of the two early breed associations in 1885. Under the gui 'ance of Solomon Hoxie, an early breeder in New York State, it continued in a desultory way through an early period of adversity, trying to survive the incubus of a fee charged largely because accurate measurements and scoring were required in addition to milk and butter production. In 1892 the requirement for entry was based on the butterfat produced in 7 consecutive days as determined by the Babcock test. Prize money offered in 1894 stimulated production testing and was the beginning of an upward surge in the volume of test work. Several agricultural colleges and breeders were advocating yearly testing at the beginning of the century, but it was not until 1908 that the association gave official recognition to this type of record.

The official butter test was inaugurated by the American Jersey Cattle Club in 1884, and the Babcock test made possible the start of the present Register of Merit in 1903. A limited number of short tests were accepted, but the yearly test soon caught the fancy of the breeders. This and the 305-day test have become standard for the breed. The first yearly record in the Register of Merit is that of Figgis 2d for 6,387 pounds of milk and 322 pounds of butterfat at 2 years and 1 month of age.

Guernsey breeders noted the interest manifested in records of cattle of other breeds, and in 1897 the American Guernsey Cattle Club offered cash prizes for yearly records made by individual cows and by groups. The results were sufficiently gratifying to justify a second contest, and in 1901 the Advanced Register of Guernsey Cattle was adopted. Provision was made for 7-day records, but this class was not popular. Glenwood Girl VI, with a record of 572 pounds of butterfat, is listed AR 1.

The Ayrshire Breeders' Association in 1902 established the Ayrshire Advanced Registry to give official recognition to production performance. No. 1 in the Advanced Registry is Rena Myrtle with 12,172 pounds of milk and 546 pounds of butterfat.

Brown Swiss breeders also set up an advanced registry for tested cows of that breed.

In reviewing the writings of chroniclers of the dairy breeds, one gains the impression that the motive which inspired the inauguration of official testing was invariably breed promotion. Publication of

records of production drew attention to record-making herds and animals. Any breed lacking this publicity soon felt the need of demonstrating the ability of its animals at the pail. One association felt that a temporary slump in the popularity of its cattle was due to the failure of its members to participate in a public production contest. Thus it appears that a desire to keep the breed constantly before the eyes of the public was a sufficient reason for testing. Breeders soon learned the individual advantage that came from the publicity attending record making. This also explains the selective testing which persisted for so long a time. Only high records drew the crowds.

After a few years production records began to have an influence on individual values. The purchase of a high-record female or the son of a tested cow carried with it the advertising value of that record. Pedigrees began to take on increasing importance when production information was included. Then, of course, this novelty in salesmanship was fully exploited, and through popular misconception of inheritance many disappointments followed purchases based on pedigree values.

Meanwhile, the leaders in dairy thought had realized the possibilities of applying the testing procedure in a broader way to commercial dairy herds. Breeders of registered cattle monopolized the official testing field, but by the use of the milk scales and Babcock test it was possible for the ordinary dairyman to assay his herd and find out which of his cows were profitable. Thus the first cow-testing association was organized in 1906. This movement to improve the earnings of dairy herds by culling unprofitable cows has spread throughout the country. Testing organizations of this type had also been established abroad in the latter part of the nineteenth century and the early part of the twentieth. The development of the movement throughout the world is summarized in table 1, which was published by the International Institute of Agriculture of Rome in 1935 (*8*).

TABLE 1.—*Development of milk recording in various countries*

Country and milk-recording organizations	Foundation year of first milk-recording organizations	Years to which figures refer	Milk-recording organizations (or recorders)	Farms practicing milk recording	Cows tested	Percentage of cows tested to total number of dairy cows
			Number	*Number*	*Number*	*Percent*
Germany	1897	1934	3,001	75,665	1,135,870	11.2
Austria	1900 [1]	1933	881	[2] 9,000	47,449	3.5
Belgium	1919–20	1933	------	------	26,339	2.9
Denmark	1895	1933–34	1,588	49,993	701,087	39.6
Danzig	(1920)	1933–34	40	802	14,748	36.8
Spain	1933	------	------	------	------	------
Estonia	1909	1934	225	5,004	37,816	9.4
Irish Free State	1910	1934	205	4,186	49,052	4.0
Finland	1898	1931	927	20,456	239,069	18.4
France	1905	1934	61	1,650	20,603	[2].5
Great Britain:						
England and Wales	1914	1932–33	49	4,598	135,902	4.6
Scotland	1903	1933	39	741	32,456	13.0
Northern Ireland	(1921)	1934	73	2,544	15,050	6.0
Hungary	1897	1932–33	53	508	20,111	2.2
Iceland	1903	1933	89	2,128	5,418	26.0
Italy	1922	1935	995	8,274	47,988	1.8
Latvia	1904	1934	846	14,033	118,799	14.7
Lithuania	1923	1933–34	137	2,634	33,201	4.0

[1] Approximately. [2] Approximate figures.

TABLE 1.—*Development of milk recording in various countries*—Continued

Country and milk-recording organizations	Foundation year of first milk-recording organizations	Years to which figures refer	Milk-recording organizations (or recorders)	Farms practicing milk recording	Cows tested	Percentage of cows tested to total number of dairy cows
			Number	*Number*	*Number*	*Percent*
Luxembourg	1933	1934	72			
Norway	1898	1933	524	9, 104	97, 767	12. 0
Netherlands (official)	1899	1932	781	15, 185	159, 157	12. 2
Poland	1904	1933–34	259	5, 237	68, 658	1. 1
Rumania	1930	1934	12	1, 213	1, 966	. 1
Sweden	1898	1932–33	931	17, 803	300, 855	14. 7
Switzerland	1922	1932–33	628	[2] 5, 000	8, 136	. 9
Czechoslovakia	1903	1934	144	4, 768	33, 867	1. 3
Total [2] [3]			12, 000	250, 000	3, 500, 000	
Argentina	1911	1934	4	33	2, 389	. 1
Canada:						
Record of performance	1911	1934			14, 883	1. 7
Testing associations		1933	332	4, 351	43, 688	
United States:						
Breed associations	1883	1934			[1] 9, 600	1. 3
Cow-testing associations	1906	1934	793	13, 694	325, 837	
Total [3]			1, 150	20, 000	400, 000	
Southern Rhodesia:						
Official and semiofficial	1929–32	1933	2	42	[2] 1, 600	
Union of South Africa:						
Official	1917	1934	32	187	1, 560	
Semiofficial	1923	1934		387	9, 074	
Total [3]			34	600	13, 000	
Australia:						
New South Wales:						
Purebred scheme	1912	1932–33			5, 214	6. 8
Grade herd testing	1912	1932–33		[2] 2, 500	63, 882	
Victoria:						
Purebred scheme	1912	1932–33			2, 802	13. 4
Grade herd testing	1921–22	1932–33	142	3, 383	104, 009	
Queensland:						
Purebred scheme		1933			[2] 700	
Grade herd testing	1910	1933		[2] 1, 000	[2] 12, 000	
South Australia:						
Purebred scheme	1912	1933			[2] 650	
Grade herd testing	1920	1933	4	[2] 100	[2] 2, 500	
West Australia:						
Purebred scheme	1918					
Grade herd testing	1932	1933			[2] 4, 000	
Tasmania:						
Purebred scheme	1914	1932–33			263	7. 2
Grade herd testing	1915	1932–33		28	5, 623	
New Zealand:						
Certificate of record test	1912	1932			[2] 400	16. 6
Government official herd test	1927	1932–33			1, 525	
Association testing	1909	1932–33	78	1, 242	23, 163	
Group testing	1923	1932–33	200	5, 090	253, 016	
Total [3]			500	14, 000	500, 000	
Grand total [3]			14, 000	285, 000	4, 500, 000	

[2] Approximate figures.
[3] Estimated totals, taking into consideration the countries where figures are lacking.

Inheritance Studies Stimulated by Production Records

The accumulation of information in the official test files on producing ability finally tempted students to delve into this material. In some cases the records were published by assembling the tested daughters of each sire. This soon drew attention to certain sires with large numbers of tested daughters, and this number came into use in preparing pedigrees. Sires of large groups of tested daughters and

those with high-producing individual progeny were extensively advertised. Because of previous emphasis on the importance of pedigree, many of these bulls were studied genealogically to determine, if possible, the source of their transmitting ability. Results of such studies were being published about 1915. Emphasis was laid on the appearance of certain ancestors in many of these pedigrees, but this began to wane when further study revealed the fact that because of the narrow foundation from which our breeds had sprung, animals selected at random were descended from about the same ancestry. Much of this genealogical material was of no value because absence of production records left it largely speculative.

WHAT *counts in building up superior inheritance in dairy cows is the number of successive crosses of sires of proved merit, uninterrupted by crosses with unproved or poor sires.*

In a herd with 12 sires there may be no female lines with more than four successive crosses of proved sires. Such a herd has made no greater progress in piling up superior inheritance than the herd that has only four proved sires, but has used them in such a way that all of them appear in several female lines of descent.

A simple way to check the progress made in concentrating superior inheritance in any herd is to compare the number of successive crosses of proved sires in the female lines with the total number of sires of proved merit in the herd.

Correction Factors for Age

It was realized at once that records made by cows of different ages were not comparable. This was recognized by the breed associations in establishing requirements for admission of cows to the advanced register. One of the first undertakings, therefore, was the study of the influence of age on production. Rough standards had been set up arbitrarily, but there was a need for more refinement. Two early publications of this nature were made by Wing (*10*) of Cornell University in 1899 and Kent (*4*) of Oregon in 1912. In both cases the factors were developed from records made by a limited number of cows in experiment station herds and they vary materially from later factors, most likely because of the small numbers. In 1917 Pearl and

Patterson (7) determined the effect of age on the milk production of Jerseys, and subsequently correction factors based on the average production of tested cows began to appear frequently. Those determined most recently doubtless have the greatest accuracy because they are based on large numbers.

The Bureau of Dairy Industry found that when correction for age was based on factors evolved only from initial test records, the reentry records showed a greater increase with advancing age than could be accounted for by age alone. This difference was attributed to development resulting from maximum production during the first test and appears to suggest that initial records only should be used in developing age correction factors. The reentry records tend to give a false picture so far as correction for age is concerned.

The procedure of adjusting records for age may still be somewhat lacking in precision. In individual cases there may be wide discrepancies, but there is room for refinement of the factors, and this should be carried on, as record material is too valuable to be neglected in breeding studies. Faults in correction factors derived from official test averages are traceable in part to the grouping of records in classes which are not limited except for age. This has been remedied in part, but there is no good reason why all records should not be reported in classes which define at least the number of milkings per day, as well as whether the record is an initial or retest record; and the rules regarding gestation requirements could be made more useful. Since the growing total of official records is the best material now available for the purpose, there seems no logical reason why its use should not be continued, enlarged, and modified to serve as a continuous base for up-to-date age-correction factors. This suggestion was made by the Bureau of Dairy Industry in 1933 [3] and changes in classifications advised which would correct many of the present faults. The adoption and use of such derived factors would result in uniformity in age-correction procedure, which is now somewhat confused by the overabundance of factors. Factors derived from this source would facilitate interclass corrections as well.

The Herd Test—a Big Step in Advance

Students of dairy-cattle breeding added much to their knowledge through the unfolding of the science of genetics. Many old theories were discarded and new methods evolved. It became apparent after a while that advanced registry records had at least two serious faults which interfered with their usefulness for genetic study: (1) Environmental conditions vary widely in different herds and are subject to abrupt and disturbing changes in the individual herd, and (2) breed-association rules complicated the situation, in some cases by establishing a large number of classifications and in others by not clearly defining the class limitations.

In most herds testing was on a highly selective basis and until recent years the breed associations reported only the animals that met the minimum requirements for entry, preferring to ignore the failures. This shortcoming proved to be a severe limitation on the use of the records for breeding studies. If a half or a third of the progeny of a given sire appeared in the test lists, one could only

[3] Graves, R. R., Fohrman, M. H., and Smith, R. H. A study of age—correction factors. A report to the production section of the American Dairy Science Association. 21 pp. Washington, D. C. 1933. [Mimeographed.]

speculate as to whether the others died, were sold, failed to meet the requirements, or did not have an opportunity to prove their ability. In most cases these groups were not random samples. This became more noticeable when progeny testing became established.

It may have been the discussion of the inadequacy of selective official testing as a help to constructive breeding, or a desire to widen the scope of testing, or both, which led to the adoption of the herd test by the Ayrshire Breeders' Association in 1925. Other major breed associations have taken similar action. The herd test requires the testing of all animals in the herd and is a big step in advance. Its helpful possibilities would seem to justify a more enthusiastic and wider patronage on the part of breeders. Its usefulness will grow in proportion to the extent of its application in herd management.

One weakness in herd testing as now conducted is the offer to cancel or conceal a low record if the animal is dropped from the breed register. This low record is part of the knowledge which testing is working to develop and to omit it is to distort what remains. What harm if the low record is published so that no one may be misled through its omission? The cancelation of the registry of the low-producing cow appears to pay for the suppression of the record. Why not brand her as a failure by publishing the record in order to protect others as well as the owner? Here is an instance of a well-conceived idea being shorn of part of its value through a desire to dodge the responsibility of telling the whole truth when it might offend.

Present herd testing is a compromise. In this respect the herd test has the same weakness as the Advanced Register or Register of Merit test, wherein the record that fell below the minimum requirement for admission to a class was not published by the breed association; or where the breeder is permitted to withdraw an animal from test if she is not producing up to his expectations or if he believes that her record will not be a credit to her sire or dam, or on a par with records that her sisters have made. Some of the sponsors of the herd test believed that the breeders feared to face the consequences of nonselective testing, and so they offered a way out when animals failed to produce satisfactorily. The extent of this compromise measures the degree by which herd testing loses its value in supplying genetic information for the breeders.

Surely those who have breed welfare at heart would wish sincerely to improve whatever is being done to assist them in breeding better cattle, and they should raise their voices in demanding that future herd testing be all-inclusive and that it be stripped of all hedges and compromises. If sires are to be proved through herd testing, how can this be fairly and equitably done if records on part of their progeny are withheld from the record because the registration papers are destroyed? What about the rights of the purchaser of an animal who judges him by what is left in the record of performance of a given sire or of the sires in his immediate ancestry? It is only by making herd testing nonselective that it will render full service to the breeders, and they have a right to demand this service through their associations.

The Development of Bull Indexes

Plant breeders were quick to adopt genetics in their efforts to improve plants. Since producing ability in dairy cattle is expressed

by one sex only, the application of genetic principles to improve this ability did not impress cattle breeders at once. The progeny of the nonproducing sex was often numerous, but cows seldom had enough daughters to afford material for inheritance studies. Record making was sporadic, and few herds had a sufficiently comprehensive testing program to furnish complete data even on the progeny of their herd sires. Despite these handicaps, the idea grew that when the production of the daughters of a sire was compared with that of their dams, the result might indicate the ability inherited by these daughters from their sire. Thus the bull-index idea originated.

One assumption used as the basis for a bull index was that the level of inheritance of a daughter is halfway between that of her sire and her dam. When the dam and daughter have been tested, two of the three quantities are known and the third, the sire's transmitting ability, may be calculated. Nils Hansson of Norway is credited with suggesting the formula, in 1913, as a method of rating sires for percentage of fat. This intermediate index is based on the well-known fact that the sire and dam contribute equally to the daughter's inheritance, but it must be kept in mind that the kind (quality) of inheritance received from each parent may not be equal.

Woodward (*11*) lists the average butterfat records of the daughters of 108 Guernsey sires as well as the average of their dams and gives the transmitting ability of the sires as determined by the intermediate index. This is perhaps the first published account of the use of this index in this country. Several other writers, including Yapp of Illinois in 1925, have since suggested its use as a method for determining the transmitting ability of bulls. Several other bull indexes have been suggested.

Pearl, Gowen, and Miner in 1919 (*6*) suggested that a sire's transmitting qualities could be measured by the difference between the yield of his daughter and her dam, but they added to it calculations based on quartile divisions of the curve of variability, and it failed in popular favor because of its complexity. In 1925 Turner (*9*) offered the following formula: Sire's potential transmitting ability equals (daughters' butter-fat production$-0.15\times$dams' butterfat production)$\div 0.85$. It is based on the premise that the daughters' butterfat production equals $0.15\times$ dams' production$+0.85\times$ sire's potential ability. This deviates from the assumption on which the intermediate index is based.

LaMaster (*5*) suggested an index based on a comparison of all records of daughters and their dams to the breed average in the various age classes. Wright introduced the breed average and number of daughter-dam comparisons into index calculations. In 1927 Goodale took account of dominance in the Mount Hope index, which was later presented in modified or commercial form, the latter being the intermediate index previously mentioned. The Missouri Agricultural Experiment Station now prefers to use the average production of all of a sire's daughters as the index of his transmitting ability.

Proved Sires and Experimental Breeding

All of these proposals were brought forward to assist breeders and students of breeding in evaluating the sire's potential ability. The need for this knowledge was based on a realization that progress in breeding depended on the use of sires that had been progeny tested,

or in other words, proved bulls. Discussion of proved sires had preceded and motivated the bull indexes, but records of breeding establishments show no evidence of any general adoption of a proved-sire program for herd improvement. This failure was often laid to the scarcity of proved sires, the difficulties encountered in moving and handling them, their uncertainty as breeders, and many minor objections. Eckles at the University of Missouri used two sires which had daughters in other herds, but they were succeeded by untried bulls. Other breeders had occasionally bought sires proved or partly proved, or secured them by trading, but most of the leading breeding establishments preferred bulls of their own breeding or young bulls selected on their pedigree and the performance of their dams.

In 1918 the Dairy Division of the Bureau of Animal Industry began a series of breeding experiments with Holstein-Friesian and Guernsey cattle at the station at Beltsville, Md. In these breeding projects there was contemplated the continuous use of proved sires to concentrate inheritance for high levels of milk and butterfat production in the herds. The continuous use of the proved sire as a means of breeding lines concentrated for high levels of production was predicated on the theory that the valuable sire for production was one that was relatively homozygous or "pure" for the hereditary factors controlling high levels of production. Furthermore, if these proved sires had the same factorial make-up, the factors for low production in the herd previously contributed from other sources would be gradually replaced by the continued use of such sires for a number of generations. The development of this theory was the result of statistical studies of Advanced Registry and Register of Merit records in the Dairy Division. Information on the relative merits of outbreeding, line-breeding, and inbreeding in furthering the end sought would develop as these projects advanced.

Descriptions of the experiments were published in Hoard's Dairyman in 1919 (*1*). In 1920 a Jersey herd was assembled to carry out part of the program. The establishment of this experimental breeding work appears to be the first attempt to use proved sires continuously for the purpose of concentrating producing ability in dairy cattle. The collateral information on the efficiency of outbreeding, line-breeding, and inbreeding should be useful in settling some of the controversial questions that trouble breeders. These experiments have been carried on under controlled conditions designed to afford all animals an equal opportunity to express their inherent ability, and no selection or culling has been tolerated.

Recommendations for the use of proved sires for herd improvement are now general and the logic of the procedure seems irrefutable. In 1929 the Bureau of Dairy Industry demonstrated the possibility of creating interest in a difficult subject by using the herediscope to illustrate in a simplified way the theory behind the method of improving producing ability in dairy cattle through the use of proved sires. These demonstrations were called breeding schools and the idea was quickly adopted as part of the dairy-extension program in many States. They have been effective in stimulating interest in better breeding. One specialist recently remarked that the breeders in his State speak a different language in discussing breeding than they used 10 years ago. Fruits of this enlightenment are bound to appear as time goes on.

Actual breeding experiments with dairy cattle are of necessity long-time undertakings beset with hazards of interference from disease. The reproductive rate is slow and only carefully planned and executed work will yield satisfactory results. Most of the early experimental breeding work with cattle was planned to start with crossing established breeds. Gowen, in 1918, describing the purposes of the cross-breeding project at the Maine Agricultural Experiment Station, said that the only method then known by which an adequate analysis of the laws of heredity could be made is by hybridization experiments so carefully planned that the segregating factors may be analyzed separately. In this experiment Holstein-Friesian, Jersey, Guernsey, Ayrshire, and Aberdeen-Angus cattle were used.

A cross-breeding experiment with Guernsey and Holstein cattle was started bv Bowlker at Framingham, Mass., in 1911. This herd was transferred to the University of Illinois in 1919, where studies were continued on the inheritance of the percentage of fat and other constituents of milk, as well as of coat color.

In 1912 the University of Wisconsin initiated a cross-breeding experiment with Jersey, Holstein-Friesian, and Aberdeen-Angus cattle for the purpose of securing genetic information through the mating of animals showing marked differences.

In all of this cross-breeding work it appears the fact was overlooked that for satisfactory results the parents of these hybrids should be as nearly homozygous for the characters studied as possible, and that careful planning should include preliminary proving of the parent stock within their respective breeds.

Breeding work similar to that planned by the Bureau of Dairy Industry was begun at the New Jersey Agricultural Experiment Station and later transferred to the California Station, where it is still in progress. The New Jersey Station more recently acquired a Holstein herd for the purpose of studying the inheritance of the percentage of fat in milk. Many other experiment stations have taken up the project of attempting to breed families characterized by high levels of production by the continued use of sires that have demonstrated their ability to transmit uniformly high production to their offspring.

This is a brief summation of the major breeding projects with dairy cattle in this country. In 1931 the committee on animal breeding, division of biology and agriculture of the National Research Council, reported that there were 85 projects relating to dairy-cattle breeding in 34 States. Many of these did not include the use of animals in the herds on projects planned to improve production.

The past two decades have witnessed a marked change in thought on the subject of cattle breeding. There is a growing appreciation of the important part genetic knowledge will play in future breeding operations as the application of this knowledge grows clearer. Discussion of old theories and beliefs is now carried on mainly for its historic interest, and greater emphasis is being laid on the importance of increasing the volume of nonselective testing and the use of progeny-tested animals for herd improvement.

Those who are interested in knowing what progress has been made toward improving the producing ability of dairy cattle will find in the appendix a list of the herds analyzed for this germ plasm survey and a brief summary of the progress made by a number of herds.

The owners of the herds that have been studied will derive benefit from having had this opportunity to observe the results of their

efforts so far, and the knowledge gained will be useful for future planning. For this purpose, a complete summary showing the transmitting ability for production levels of the sires used, is being returned to the owners of all herds that have contributed data. It might be well to emphasize again that the conclusions drawn from the survey are based on the generally accepted theory that butterfat and milk production are characters inherited through quantitative factors; that, on the average, sires proved for ability to increase daughters' records over dams' carry superior germ plasm; and that where a number of such sires have been used successively in a herd, progress has been made in improving the germ plasm of the herd for higher levels of production.

The Procedure Used to Evaluate Germ Plasm for Producing Ability

A PLAN of procedure was formulated for analyzing the material from the herds surveyed in such a manner as to make it possible to derive a maximum of useful information from it. With full appreciation of the fact that so much of the breeding data came from herds whose owners had no advanced training in mathematics or genetics, the study and tabulation of results was planned so that it would be of real value to those cooperating as well as to the specialists who would use it in teaching and extension work. Complex mathematical analyses and abstruse terminology were avoided.

No herd is better than the sires that have been used in its development. With this thought in mind, the genetic make-up of a herd may be likened to an unfinished structure into which certain materials have gone in varying quantities. The soundness or quality of the structure depends on the relative amounts of high-, medium-, and low-grade units that together make it a whole. Herd sires are the main contributors of the germ plasm that goes into the building of a herd of cattle, and when production information is available on a sufficiently large number of a sire's daughters and their dams, then the quality of his germ plasm may be analyzed and recorded. When the sires have been assayed, the outline of the herd indicates what contribution each sire has made in building it. If all sires have a genetic make-up for transmitting high production, the result should be progress in bettering the germ plasm, and a series of poor sires, of course, would generally produce the opposite results. Some further advance may be traced to the influence of females that transmit good inheritance, and other limited modifications may come about through selection.

Producing ability can be studied only where satisfactory records are available. For the purposes of this survey the needed material could be supplied solely by herd owners who had had a program of continuous testing sufficiently long to have proved at least two of the sires used. Sires were considered as proved if they had five or more tested daughters from tested dams without too much selection. This was established as the minimum requirement for herd analysis.

The value of the results of the survey are *contingent on the accuracy and reliability of the data submitted, which, in turn, depended upon the judgment of the field workers. Information was accepted and analyzed as submitted from the field.*

The first step in organizing the survey was the preparation of forms to be used for gathering the necessary information in the field so that it could be submitted for analysis. The method of study was designed to include all record material available in the herds from the time test work was started, so that a complete herd history could be reviewed and studied. This was to be primarily a herd analysis, and the forms were prepared with that object in mind.

When the forms were ready the survey was begun by sending sets of forms with directions for their use to the State agricultural colleges and experiment stations. These institutions had been testing their herds for production over a long period of years and in most cases the records were kept in such a manner as to make them readily available. The idea was to assemble data on as many of these station herds as possible in order to establish a procedure with the workers for securing the information needed for herd analysis. It was fully appreciated that the organization and training of a large field force to carry on the survey of the commercial herds would be a big undertaking. A book of instructions for securing and compiling field data was sent to the field workers.

A set of sire cards showing the data from a commercial herd that had used three sires, each with a sufficient number of daughters to enable them to be analyzed as proved sires, is shown in the following pages. This herd is chosen for illustration here, not as the best herd but because no sires had been used that had too small a number of daughters to justify an analysis; because the number of sires involved was so small that the cards would take up only a few pages; and because the data indicate progress in improvement of the germ plasm for higher levels of production.

The numbers in the left-hand column of the sire cards marked "space number" are key numbers which can be used as a guide for keeping in proper alinement the descendants of the various foundation cows. The foundation cows are listed on the first or left-hand card of the series. As these cards are made up, on line 1 under Dam number is shown no. 107452, on line 4, no. 172535, on line 9 no. 148725, etc. These are the registration numbers or names of the foundation cows. On the same line with each number certain information is given for each of the foundation cows, which is as follows for no. 107452: Age tested—8 years; days in milk—334; number of milkings—668; actual production, milk—6,943 pounds, butterfat—348 pounds, percentage of butterfat—5.01 percent; calculated production milk—6,943 pounds, butterfat—348 pounds.

Proceeding to the right on the next card (p. 1016), the daughters of sire no. 1, Maybelle's Crescent 78095, are listed. On line 1 under Dam number is no. 107452, the same as shown on line 1 of the preceding card. She is a foundation cow and is the dam of no. 248669, a daughter of Maybelle's Crescent, the sire whose name heads this card. Following her number 248669 is the information on her milk and butterfat, in the same order as given for her dam. In a like manner no. 272395, on line 4 of this card, is a daughter of Maybelle's Crescent out of the foundation cow no. 172535.

Cooperative Survey of Plant and Animal Improvement

DAIRY SIRE CARD (1)

Card number 1.
Herd owner
Post office address
Name of sire, Foundation cows.
Years used in herd, 19 to 19 .

Breed, Guernsey.

Reg. number
Date data assembled, Oct. 7, 1935.

Space number	Dam number	Daughter number	Age tested Y.	Age tested M.	Days in milk	Number of milkings	Days carried calf	Actual production Milk, lb.	Actual production Butter fat, lb.	Actual production Butter fat, pct.	Calculated production Milk, lb.	Calculated production Butter fat, lb.	Type
1	107452		8		334	668	242	6,943	348	5.01	6,943	348	
2	107452												
3	107452												
4	172535		5		317	634	285	5,791	303	5.23	5,907	309	
5	172535												
6	172535												
7	172535												
8	172535												
9	148725		13		329	658		9,548	404	4.23	9,548	404	
10	148725												
11	148725												
12	148725												
13	Hite		8		262	524		6,960	322	4.63	6,960	322	
14	Hite												
15													
16	Dolly		7		365	730	199	7,371	328	4.45	7,371	328	
17													
18	Dolly												
19	Dolly												
20													
21	Red		4		304	608		5,839	284	4.86	6,213	302	
22													
23	Wisconsin Hazel.		5		320	640	228	10,458	548	5.24	10,667	559	
24	Maryann		6		280	560		7,569	349	4.61	7,569	349	
25	Maryann												
26	Peggy I		7		307	614	153	6,665	246	3.69	6,665	246	
27	Peggy I												
28	Almira		4		365	730	213	9,566	557	5.82	10,178	593	
29	Lena		6		343	686	261	6,997	316	4.52	6,997	316	
30	Lena												
31	Lena												
32	Cowaster[1]												
33	Hazel[1]												
34	Lill[1]												
35													
36													
37													
38													
39													
40													

	Butter fat, pct.	Milk, lb.	Butter fat, lb.	Type
Average production of 11 tested dams, Foundation cows in	4.75	7,729	871	
Average production of — daughters in this generation having tested dams in				
Average production of their respective dams in				
Number of daughters excelling their dams in				
Percentage increase or decrease of daughters in				

[1] No record.

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DAIRY SIRE CARD (1)

Card number 2. Breed, Guernsey.
Herd owner
Post-office address
Name of sire, Maybelle's Crescent. Reg. number 78095.
Years used in herd, 1925 to 1928. Date data assembled, Oct. 7, 1935.

Space number	Dam number	Daughter number	Age tested Y.	Age tested M.	Days in milk	Number of milkings	Days carried calf	Actual production Milk, lb.	Actual production Butter fat, lb.	Actual production Butter fat, pct.	Calculated production Milk, lb.	Calculated production Butter fat, lb.	Type
1	107452	248669	8		323	646	263	8,826	442	5.01	8,826	442	
2	107452	248669											
3	107452	248669											
4	172535	272395	3		365	730	260	7,643	397	5.19	8,782	456	
5	172535	272395											
6	172535	298192	3		365	730	190	8,470	428	5.05	9,732	492	
7													
8													
9	148725	246442	5		280	560		7,080	336	4.75	7,222	343	
10	148725	246443	2		327	654	275	6,887	335	4.86	8,912	433	
11													
12													
13	Hite	Cad	5		326	652	100	10,086	390	3.87	10,288	398	
14	Hite	Cad											
15	Cad	Topsy	6		316	632	253	10,278	413	4.02	10,278	413	
16	Dolly	Eve	5		273	546	253	7,140	325	4.55	7,283	331	
17													
18													
19													
20													
21	Red	Red 2	4		310	620	230	9,155	426	4.65	9,741	453	
22													
23													
24	Maryann	Daisy	3		343	686	201	9,215	378	4.10	10,588	434	
25	Maryann	Bonnie	3		339	678	316	5,556	270	4.86	6,384	310	
26	Peggy I	Spot	4		365	730	0	5,968	289	4.84	6,350	307	
27													
28													
29													
30													
31													
32	Cowaster	Jesse	5		364	728		10,127	449	4.43	10,329	458	
33	Hazel	Peggy 2	2		365	730	155	7,865	341	4.34	10,177	441	
34	Lill	Lill 2d	2		302	604	279	6,173	308	4.99	7,988	398	
35													
36													
37													
38													
39													
40													

	Butter fat, pct.	Milk, lb.	Butter fat, lb.	Type
Average production of 15 tested daughters in	4.63	8,859	407	
Average production of 12 daughters in this generation having tested dams in	4.65	8,699	401	
Average production of their respective dams in	4.55	7,541	339	
Number of daughters excelling their dams in	7	6	10	
Percentage increase or decrease of daughters in	2.2	15.4	18.3	

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DAIRY SIRE CARD (1)

Card number 3.
Herd owner.....
Post-office address...........................
Name of sire, Burrow's Farm Polly Knight.
Years used in herd, 1928 to 1931.

Breed, Guernsey.

Reg. number 99307.
Date data assembled Oct. 7, 1935.

Space number	Dam number	Daughter number	Age tested Y.	Age tested M.	Days in milk	Number of milkings	Days carried calf	Actual production Milk, lb.	Actual production Butterfat, lb.	Actual production Butterfat, pct.	Calculated production Milk, lb.	Calculated production Butterfat, lb.	Type
1	248669	287108	3		332	664	244	9,128	500	5.48	10,488	574	
2	248669	324985	3		340	680	240	6,958	350	5.03	7,995	402	
3													
4	272395	279273	5		323	646	245	8,755	473	5.40	8,930	482	
5													
6													
7	172535	296517	4		310	620	275	7,450	416	5.58	7,927	443	
8													
9													
10													
11	148725	324986	2		354	708	246	6,445	328	5.09	8,340	424	
12	148725	288170	4		283	566	275	8,482	428	5.05	9,025	455	
13	Cad	Cad's Lucy	2		335	670	252	8,241	436	5.29	10,664	564	
14	Cad	Chloe	2		296	592		7,642	347	4.54	9,889	449	
15													
16	Eve	Ellen	3		314	628	218	8,372	418	4.99	9,619	377	
17													
18	Dolly	Dolly Boss	4		365	730	192	10,066	521	5.18	10,710	554	
19	Dolly	Boss II [1]											
20	Boss II	Dimple	2		337	674	263	10,279	505	4.91	13,301	653	
21	Red 2	Muley	3		326	652	30	8,820	414	4.69	10,134	476	
22													
23	Hazel.	Bess	3		329	658	218	7,877	426	5.41	9,051	489	
24													
25													
26													
27	Peggy I	Peggy's Fay	5		306	612	268	10,146	452	4.45	10,349	461	
28	Almira	Alma	2		365	730	283	7,663	465	6.07	9,916	602	
29	Lena	Lela	3		323	646	217	8,163	423	5.18	9,379	486	
30													
31													
32													
33													
34													
35													
36													
37													
38													
39													
40													

	Butterfat, pct.	Milk, lb.	Butterfat, lb.	Type
Average production of 16 tested daughters in	5.15	9,732	493	
Average production of 15 daughters in this generation having tested dams in	5.16	9,494	483	
Average production of their respective dams in	4.64	8,728	405	
Number of daughters excelling their dams in	15	9	13	
Percentage increase or decrease of daughters in	11.2	8.8	19.3	

[1] No record.

U. S. D. A.

38143°—36——65 ××

DAIRY SIRE CARD (1)

Card number 4. Breed, Guernsey.
Herd owner
Post-office address
Name of sire, Highland's Ajax. Reg. number 100112.
Years used in herd, 1930 to 1932. Date data assembled, Oct. 7, 1935.

Space number	Dam number	Daughter number	Age tested Y.	Age tested M.	Days in milk	Number of milkings	Days carried calf	Actual production Milk, lb.	Actual production Butter fat, lb.	Actual production Butter fat, pct.	Calculated production Milk, lb.	Calculated production Butter fat, lb.	Type
1	287108	356497	2		347	694	262	7,814	414	5.30	10,111	536	
2													
3	248669	340805	2		330	660		8,646	425	4.91	11,188	550	
4	279273	366724	3		200	400	135	7,179	351	4.89	8,249	[1] 403	
5	272395	337020	2		204	408		3,320	184	5.54	4,296	[1] 238	
6	298192	371783	2		365	730	249	8,478	477	5.63	10,970	617	
7													
8	172535	344515	2		332	664	250	6,535	365	5.58	8,456	472	
9													
10													
11													
12													
13	Cad's Lucy	Lou	2		335	670	249	6,904	357	5.17	8,934	462	
14													
15													
16													
17	Eve	Evelyn	2		333	666	177	7,876	414	5.26	10,191	536	
18													
19													
20													
21	Muley	Molly	2		324	648	214	9,918	489	4.93	12,834	633	
22	Muley	Marvel	2		364	728	262	7,371	367	4.98	9,538	475	
23													
24													
25													
26													
27													
28													
29													
30	Lena	Lotta	2		317	634	238	7,140	346	4.85	9,239	448	
31	Lena	Letty [2]											
32													
33													
34	Lilly 2d	Lady	2		362	724	290	8,210	424	5.16	10,624	549	
35													
36													
37													
38													
39													
40													

	Butter fat, pct.	Milk, lb.	Butter fat, lb.	Type
Average production of 12 tested daughters in	5.18	9,553	493	
Average production of 12 daughters in this generation having tested dams in	5.18	9,553	493	
Average production of their respective dams in	5.01	8,822	443	
Number of daughters excelling their dams in	8	7	7	
Percentage increase or decrease of daughters in	3.4	8.3	11.3	

[1] 7-month record.
[2] No complete record.

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DAIRY SIRE CARD (2)

Untested daughters

Card number 4.

Space number	Daughter number	Reasons for absence of record or disposal
		This bull has daughters in W. H. Meyer's herd, Arcadia, Ind.

Total number daughters old enough to have completed records at time of survey, 13.
Percent of daughters with records, 100.

Environmental conditions

1. Ration fed: 400 gr. sc., 200 oats, 100 gr. soybeans.
2. Ratio of grain to milk produced: 1 to 3 or 3½.
3. Quality and kind of roughage: Good corn silage, alfalfa hay.
4. Conditions of test:
   A. Stanchion: 6 months' pasture season, bluegrass, alfalfa
   B. Kind of test.[1] D. H. I. A.
   C. Other conditions affecting production: None.
5. Health: Good.
   A. Tuberculosis: No.
   B. Abortion: No.
   C. Udder troubles: No.
   D. Miscellaneous: None.

Description of type of offspring of sire

1. Unusual color markings: No.
2. Malformed calves: No.
3. Comparison of daughters with dams in—
   A. Size (weight): Not quite as large, more refined.
   B. Shape of udder: As good or better than dams.
   C. Top line: Slight improvement over dams.
   D. Other points:[2] Persistent milkers, slightly lowered test, good ability to consume roughage.

[1] Advanced Register, herd test, or Dairy Herd Improvement Association.
[2] A tendency to lay on fat, to lack persistency in yield, to be hard milkers, to be delicate feeders, or other items that affect so many daughters as to indicate an inherited trait, should be noted.

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The next card (p. 1017) lists the daughters of sire no. 2, Burrow's Farm Polly Knight 99307. On line 1 is found no. 287108, one of his daughters whose dam is no. 248669, a daughter of the preceding sire and the foundation cow no. 107452, all shown on line 1. Farther down the card in space 7 is another daughter of Burrow's Farm Polly Knight. She was no. 296517 and her dam is the foundation cow no. 172535. The fact that space 7 is blank on the second card indicates that daughter no. 296517 comes directly from the foundation cow.

The fourth card (p. 1018) carries the daughters of the third sire, Highland's Ajax 100112. On line 1, his daughter no. 356497 is from cow no. 287108, a daughter of Burrow's Farm Polly Knight, and traces back to foundation cow no. 107452 through no. 248669. This is a straight female line. On line 8, daughter no. 344515 comes directly from the foundation cow no. 172535. All the production information is given as explained above.

When these cards are spread side by side, they enable one to trace the descent of each female back through the various sires to the foundation cows.

When these cards, filled out, were received in the Department, the first step in the analysis was to construct a cross chart or herd pedigree, showing the female line of descent horizontally and the descendants of the various sires in vertical columns. This was a check on the correct arrangement of individuals as given on the cards. Only the individual animal's number or name is given in the chart. The chart for the herd illustrated on the cards is shown in table 2.

Table 2.—*Herd pedigree, showing female line of descent and daughters of proved sires*

Foundation cows	Daughters of sire 1	Daughters of sire 2	Daughters of sire 3
107452	248669	287108	356497.
107452	248669	324985	
107452	248669		340805.
172535	272395	279273	366724.
172535	272395		337020.
172535	298192		371783.
172535		296517	
172535			344515.
148725	246442		
148725	246443		
148725		324986	
148725		288170	
Hite	Cad	Cad's Lucy	Lou
Hite	Cad	Chole	
Hite	Cad—Topsy [1]		
Dolly	Eve	Ellen	
Dolly			Evelyn.
Dolly		Dolly Boss	
Dolly		Boss II N. R.	
Dolly		Boss II N. R—Dimple [2]	
Red	Red 2	Muley	Molly.
Red	Red 2	Muley	Marvel.
Wisconsin Hazel		Bess	
Maryann	Daisy	Bubbles N. R	
Maryann	Bonnie		
Peggy I	Spot		
Peggy I		Peggy's Fay	Flip N. R.
Almira		Alma	
Lena		Lela	
Lena			Lotta.
Lena			Letty N. R.
Cowaster N. R	Jesse		
Hazel N. R	Peggy 2		
Lille N. R.	Lill 2d		Lady.

Total—foundation cows, 14; daughters of sire 1, 15; daughters of sire 2, 18; daughters of sire 3, 14.

[1] Topsy is an inbred daughter of sire 1 out of his daughter Cad.
[2] Dimple is an inbred daughter of sire 2 out of his daughter Boss II.

The letters N. R. following the name of an individual animal indicate that that animal did not have a record at the time of this survey. Note the arrangement for indicating inbred daughters. In the column under sire 1, Topsy is an inbred daughter of sire 1, out of his daughter Cad. In the column under sire 2, the cow Dimple is shown to be inbred and out of the cow Boss II.

In the first line, cow no. 248669 is a daughter of the foundation cow, no. 107452, by sire 1; no. 287108 is a daughter of no. 248669 by sire 2; no. 356497 is a daughter of no. 287108 by sire 3. Where a line is thus completely filled out it indicates the continuous use of proved sires in regular order.

Dotted lines across a vertical column that does not have numbers or names of females indicate the jumping or bridging of a sire generation on the chart. Cow no. 248669, a daughter of sire 1, is the dam of cow no. 340805, a daughter of sire 3. The absence of number or name on the line connecting cow no. 248669 and cow no. 340805 indicates that sire 2 does not enter into this line of descent.

THE METHOD OF RATING SIRES

The method of rating sires for the survey was so formulated as to consider their breeding value irrespective of the general type of management in different herds. It was also necessary to avoid discrimination in favor of herds in which the testing of cows has developed to a speciality, or against herds handled under everyday dairy farm conditions.

Age correction factors were used so that records might be compared. Corrections for age and for other variables were given in a book of instructions. The correction factors were derived mostly from breed-association data, but the general suggestion was that where conditions of testing varied in the herd, all records were to be corrected to the basis of the class or type of record most commonly used in the herd. Unfortunately, in some cases this recommendation was overlooked or ignored and all records were raised to an artificial level not true for the herd as a whole. This, of course, did not affect the scoring of the various sires in relation to one another but merely raised all averages above the customary level, which may be flattering but is also confusing to the owner and his acquaintances. Time was too limited to recalculate all records and the data were used as submitted, except where errors of identification or calculation were obvious, or where adjustments were too much out of line. Corrections were made in such cases where possible; if not, the records were discarded. Short-time records were scanned closely, and if adjustments made them too far out of line they also were discarded.

The three bases on which the worth of a sire was judged were (1) the improvement in production of his daughters over their dams, (2) the proportion of daughters equal to or better than their dams, and (3) the relation of the production of the dams to the herd average. The first two bases had been employed by this Bureau in previous studies of this nature.

The first indication of merit in a sire is his ability to beget daughters that produce more than their dams. Without this increase, there is no absolute assurance of progress in producing ability. The importance of an increase or decrease in production gives this measure first place in the rating of sires. To discount the variations in herd practices previously referred to, the difference between the average

production of daughters and their dams was converted to a percentage basis.

The second measure of a sire's value as a herd improver is the proportion of his daughters that excel their dams as producers. There were many small groups in this study, and with a minimum of five pairs, a single extremely high or extremely low record distorts the average in such groups. Consistency in improving a large proportion of the daughters was given additional credit, and this tended to counterbalance any abnormal rating caused by the undue influence of extreme individual records on the average of the group. The number of daughters excelling their dams was expressed as a percentage so that groups of varying sizes might be compared.

The third factor given above was used as a modifier, to make compensating adjustment between sires, necessitated by differences in the relative merit of their groups of mates. Breed averages are based on selected lots of animals and they usually represent a composite of various environmental conditions, whereas in most cases each herd has a distinctive environmental set-up. The average production of the individual herd was therefore selected as the standard by which the dam groups should be judged. Adjustment in the sire's ratings was made according to the variation of the average production of his mates from the cumulative herd average, expressed as a percentage of the herd average.

The cumulative herd average was started with the production of the foundation cows. To this was added the production of all daughters of the various sires used in the herd. With each new proved sire, the average of all preceding production records in the herd was calculated, and this constituted the cumulative herd average. For each proved sire a new cumulative herd average was figured.

The above three bases give consideration to the important factors that must be considered in determining what a sire has accomplished in herd improvement, and when they are expressed as percentages, the influence of the method of management on the level of production is disregarded and all sires are treated alike. The three points considered are not necessarily of equal weight or importance, but it is essential that they be built into a composite score. This was done by a system of plus and minus point scoring.

The increase or decrease of the daughters' average production above or below that of their dams was scored by allowing 1 plus point for each 0.2 percent increase and 1 minus point for each 0.2 percent decrease. If 50 percent of a sire's daughters exceeded their dams, no points were scored, but 1 plus point was scored for each 1 percent or fraction thereof above 50 percent and 1 minus point for each 1 percent or fraction thereof below 50 percent. When the dam of a sire's daughters averaged above the cumulative herd average, he received 1 plus point for each 0.5 percent above. One minus point was scored for each 0.5 percent by which the dams' average was below the herd average.

The algebraic sum of these three partial scores is the total score for the bull. (See the chart on p. 1024.)

Broad Classification Better Than Hairsplitting

Environment plays a prominent part in the making of production records, and the use of correction factors often makes the effect of environment even more confusing. With this in mind, it is easy to

understand why analyzing a sire or herd is not a precise undertaking. Efforts to assign definite mathematical values to the transmitting ability of dairy sires are apt to bog down in a morass of records made soggy by corrections for this, that, and the other. A man's height can be measured in inches and his weight in ounces, and this can be done immediately, but a cow's record, which is the expression of her inherited ability, is made over a period of time. Favorable environment helps her to make the best of her ability, but what about the unavoidable upsets such as careless feeding, a gouge from the horn of a stable mate, unseasonable weather, and a host of other disturbing influences? It is presumptuous to state a sire's ability in exact pounds of milk or fat when the estimate is based on a number of his daughters' records made under such varying conditions.

If hairsplitting exactitude is set up merely as a means for deciding competitions between bull owners, then it is apt to prove detrimental to breed betterment because this competition offers a temptation to the overzealous. "Cow jockeys" have often interrupted advances in dairy-cattle breeding. Broader classifications serve far better in rating bulls than the exact figures given to represent transmitting ability in pounds of milk and percentage of butterfat. Basically, sires are either good or poor transmitters. If they improve the herd, they are good, and if they pull it down, they are poor. A herd that has been bred up from a series of bulls all of which have been improvers is bound to be accumulating superior germ plasm.

For convenience, some subdivision of the good bulls was deemed desirable and an empirical division was adopted. When the analyzing of the first 30 college herds was completed, 137 proved bulls had been scored. These were assembled according to scores and the limits of the subclasses were established. For percentage of fat, 77 sires had positive scores and 60 negative. Twelve bulls, or about 9 percent, scored 70 or more points; they were marked "E", or excellent. Twenty-six, or 19 percent, scored 35 to 69 points and were called "G", or good; 39, or 28½ percent, scored 0 to 34 points and were rated "F", or fair; 16, or 11.7 percent, had 1 to 14 minus points and were so close to the border line that they were classed as "U", or undeterminable. In most cases these undeterminable sires made no noticeable change in the germinal make-up of the herd. The remaining 44 sires scored 15 or more minus points and were marked "P", or poor.

For milk and butterfat there were 76 and 79 bulls, respectively, with positive and 61 and 58, respectively, with negative scores. The range of production was wider than for percentage of fat; consequently, the scores were higher. In milk 22 and in butterfat 18 bulls scored 100 or more plus points and were called "E." Twenty-seven scored 50 to 99 in both classes and were marked "G", while 27 for milk and 34 for butterfat scored 0 to 49 and were called "F." Those marked "U" scored 1 to 14 minus points—there were 10 of these for milk and 15 for butterfat; and 51 and 43 scored 15 or more minus points for milk and butterfat, respectively, and were rated "P."

All sires with less than five daughters from tested dams were marked "NP," or not proved.

Of the five classes, the first three, "E", or excellent, "G", or good, and "F", or fair, all showed ability to improve the genetic make-up of the herds. The "U", or undeterminable, class made very little change, but the "P", or poor, sires failed to measure up to their owners' hopes and lowered the quality of the germ plasm in the herds.

When these designations are applied to the sires in the herd pedigrees, the upward or downward trends can be closely followed, and the chart affords a good picture of the germinal constitution of the herd as far as the analysis is carried.

The method of scoring sires is summarized briefly as follows:

Method of scoring sires for inheritance for butterfat percentage, level of milk production, and level of butterfat production

A. Percentage increase or decrease of the daughters compared with dams.
 1. 1 plus point for each 0.2 percent increase over the dams.
 2. 1 minus point for each 0.2 percent decrease below the dams.

B. Percentage of daughters better than dams.
 1. 1 plus point for each 1 percent or fraction thereof above 50 percent.
 2. 1 minus point for each 1 percent or fraction thereof below 50 percent.

C. Percentage by which the average of the dams is above or below the herd average (correction for level of production).
 1. 1 plus point for each 0.5 percent by which the average of the dams is above the herd average—or 2 points for each 1 percent above the herd average.
 2. 1 minus point for each 0.5 percent by which the average of the dams is below the herd average.

D. Rating of sires on basis of total number of points secured under A, B, and C.

	Butterfat percentage	Milk and butterfat
1. E (excellent)	+70 points or more.	+100 points or more.
2. G (good)	+35 to +69 points.	+50 to +99 points.
3. F (fair)	0 to +34 points.	0 to +49 points.
4. U (undetermined)	−1 to −14 points.	−1 to −14 points.
5. P (poor)	−15 points or more.	−15 points or more.

Herd summary form, showing the succession of sires used in this herd and their ability to transmit production, and indicating the various steps used in evaluation

Name of sire	Maybelle's Crescent—78095 No. 1			Burrow's Farm Polly Knight—99307 No. 2			Highland's Ajax—100112 No. 3		
a. Number of tested pairs	12			15			12		
	Butterfat	Milk	Butterfat	Butterfat	Milk	Butterfat	Butterfat	Milk	Butterfat
	Percent	*Pounds*	*Pounds*	*Percent*	*Pounds*	*Pounds*	*Percent*	*Pounds*	*Pounds*
b. Average of daughters	4.65	8,699	401	5.16	9,494	483	5.18	9,553	493
c. Average of their dams	4.55	7,541	339	4.64	8,728	405	5.01	8,822	443
d. Increase ($b-c$) or decrease ($c-b$)	+0.10	+1,158	+62	+0.52	+766	+78	+0.17	+731	+50
e. $\frac{d}{c}\times 100$ (percentage)	+2.2	+15.4	+18.3	+11.2	+8.8	+19.3	+3.4	+8.3	+11.3
f. Number of daughters equal to or better than dams	7	6	10	15	9	13	8	7	7
g. $\frac{f}{a}\times 100$ (percentage)	58.3	50.0	83.3	100.0	60.0	86.7	66.7	58.3	58.3
h. Cumulative herd average	4.75	7,729	371	4.68	8,381	392	4.86	8,896	430
i. $\frac{c}{h}\times 100$ (percentage)	95.8	97.6	91.4	99.1	104.1	103.3	103.1	99.2	103.0
j. Score of bull for *e*	+11	+77	+92	+56	+44	+97	+17	+42	+57
k. Score of bull for *g*	+9	0	+34	+50	+10	+37	+17	+9	+9
l. Score of bull for *i*	−8	−5	−17	−2	+8	+7	+6	−2	+6
m. Total of *j*, *k*, and *l*	+12	+72	+109	+104	+62	+141	+40	+49	+72
n. Classification of bull	F	G	E	E	G	E	G	F	G
o. Notes on feeding and management, Dairy Herd Improvement Association	2 milkings			2 milkings			2 milkings		
p. Total daughters sired that calved in this herd	15			18			13		
q. Total daughters tested	15			16			12		
r. $\frac{q}{p}\times 100$ (percentage)	100.0			88.9			92.3		
s. Qualifying statements				1 short record not used			1 short record not used		
t. Average for all tested daughters	4.63	8,859	407	5.15	9,732	493			

A herd summary form is reproduced here which illustrates the scoring and rating system as applied to the various sires in this herd. Below the first sire's name on line *a* the number 12 is the number of his tested daughters from tested dams. Line *b* shows that these 12 daughters averaged 4.65 percent of fat, 8,699 pounds of milk, and 401 pounds of fat. The averages of the dams of these daughters, given on line *c*, were 4.55 percent of fat, 7,541 pounds of milk, and 339 pounds of fat. The average increases of daughters over dams are 0.10 percent of fat, 1,158 pounds of milk, and 62 pounds of fat as shown on line *d*. On line *e* these amounts are expressed as percentages of the averages of the dams—2.2, 15.4, and 18.3 percent, respectively. Line *f* shows the number of daughters which were equal to or better than their dams—7 for fat percentage, 6 for milk, and 10 for fat production. These are, respectively, 58.3, 50, and 83.3 percent of the total of 12 daughters, as given on line *g*. The cumulative herd average when this sire came into the herd was 4.75 percent of fat, 7,729 pounds of milk, and 371 pounds of fat (line *h*), and the average of the dams to which sire 1 was mated was 95.8, 97.6, and 91.4 percent of the cumulative herd average for percentage of fat, milk production, and fat production, respectively, as shown on line *i*. The information on lines *a* to *g* is drawn from the summary at the bottom of the original sire cards. Lines *h* and *i* are calculated from these same cards.

The point scoring begins on line *j*. Five plus points are given here for each 1 percent increase shown on line *e*. For percentage of fat, 5 times 2.2 percent is 11 points; for milk production, 5 times 15.4 percent is 77 points; for fat production, 5 times 18.3 percent is 92 points. On line *k*, 1 point is given for each 1 percent or fraction thereof over 50 percent on line *g*. This figures out as 9 points for fat percentage, 0 for milk production, and 34 points for fat production. On line *l*, 2 plus points are given for each 1 percent over 100 percent on line *i*, and 2 minus points for each 1 percent below 100 percent. For percentage of fat, 95.8 percent (line *i*) is 4.2 percent below 100 percent, and the score given is therefore 8 minus points. For milk production, 5 minus points are given because 97.6 percent is 2.4 percent below 100 percent. For fat production, 17 minus points are given since 91.4 percent is 8.6 percent below 100 percent.

The scores on lines *j*, *k*, and *l* are totaled on line *m*. In this example there are 12 plus points for percentage of fat, 72 plus points for milk production, and 109 plus points for fat production. The point score limits for final classification or designation of sires are given in a previous table. For percentage of fat a score of 12 plus points falls between 0 and 34, the limits of the F, or fair, class. For milk production, the score of 72 plus points falls between 50 and 99, the limits of the G, or good, class. For butterfat production, the score of 109 plus points exceeds 100, the lower limit of the E, or excellent class. These designations are given on line *n*.

Line *o* carries notes on feeding and management, drawn from the original sire cards. Line *p* shows the total number of daughters that calved in the herd and line *q* the number tested. This is expressed on line *r* as the percentage of the total number that calved in the herd. Line *s* is for qualifying statements covering conditions bearing on the accuracy of the data submitted. Line *t* was added to

provide space for the average records of all daughters of each sire. This includes those listed on line *b* together with any additional daughters whose dams have no records.

It should be borne in mind that the designations given on line *n* are based entirely on the performance of the sire's daughters in the herd under survey and under the conditions existing in the herd when the records were made. This study is an analysis of herds, and the individual sires are only parts of these herds. Whether or not a given sire would rate a similar designation in another herd under different conditions is purely speculative and not of importance for this survey. He has been rated here on what he has accomplished in improving the production of the herd studied.

With this summary sheet before us, it might be well to review how well these designations define the performance of these three sires in this herd.

Beginning with percentage of fat, the 12 daughters of sire 1 averaged 4.65 percent, an increase of 0.10 over their dams, and 7 of 12 equalled or excelled their dams. Even though the average of the dams was slightly below the herd average, this sire deserves a fair rating. Fifteen daughters of sire 2 averaged 5.16 percent, which is 0.52 better than their dams, and every daughter exceeded her dam. Such performance is excellent, as labeled. Sire 3 had 12 daughters averaging 5.18 percent from dams which averaged 5.01, and 8 of the 12 equalled or exceeded their dams, which deserves to be called good. Thus three daughter groups show consistent improvement for fat percentage.

In milk production the 12 daughters of sire 1 averaged 8,699 pounds, averaging 1,158 pounds more than their dams. Six exceeded their dams and the average increase is sufficient to make this a good sire. The next sire's 15 daughters averaged 9,494 pounds of milk, an increase of 766 over their dams, and 9 of the 15 were better producers than their dams. The mates of this sire were 4 percent above the herd average, and his performance was good. Twelve daughters of sire 3 averaged 9,553 pounds, or 731 more than their dams. Seven of 12 were better than their dams, and the latter were about average for the herd. The substantial increase in production shown by the daughters and the fact that the majority of the daughters were better than their dams earned this sire the designation of fair.

Butterfat production shows these sires to the best advantage as they were consistently good in percentage of fat and milk production. Twelve daughters of sire 1 averaged 401 pounds of butterfat, or 62 more than their dams, with 10 of the 12 exceeding their dams. A rating of excellent is deserved. Sire 2 has 15 daughters with an average of 483 pounds of fat from dams averaging 405. The increase is 78 pounds of fat, with 13 of 15 daughters better than their dams. This again is excellent performance. Twelve daughters of sire 3 averaged 493 pounds of fat, an increase of 50 over their dams, and 7 of the 12 exceeded their dams. This sire is rated good.

Such detailed analysis brings out the benefits wrought by sires of this caliber.

Limitations of space made it necessary to omit the detailed discussion and instead a condensed summary was prepared for each herd. These summaries are given in the appendix. The abbreviated information for the above herd is given here in condensed form as an illustration of what the summaries contain.

Condensed summary form

Sire No.	Pairs of dam and daughter	Ratings of sires			Name of sire
		Percent	Milk	Fat	
1	12	F	G	E	Maybelle's Crescent—78095.
2	15	E	G	E	Burrow's Farm Polly Knight—99307.
3	12	G	F	G	Highland's Ajax—100112.
Total	39				
Number of daughters better than dams.		30	22	30	
Herd average		4.93	9,042	444	Based on records of 54 cows.
Average of daughters of last sire		5.18	9,553	493	
Conditions		2 milkings			

5 female lines of descent with 3 successive crosses of proved sires.
11 female lines of descent with 2 successive crosses of proved sires.

The proved sires in the herd are listed vertically in their regular order. After each sire's number is shown the number of his tested daughters from tested dams. Then follow the sire ratings or designations for percentage of fat, pounds of milk, and pounds of butterfat. This gives at a glance the computed quality of the sires, their sequence in the herd, and the number of daughters. Names of the sires are listed in the last column.

If one or more NP (not proved) sires were used in the herd, their numbers are assembled in a space below the number of the last proved sire, and the total of their paired tested daughters is also given.

The total number of tested daughters from tested dams is given opposite the word "total", and below the ratings of sires is the total number of such daughters that exceeded their dams for percentage of fat, pounds of milk, and pounds of butterfat.

Next comes the herd average based on all cows tested as reported in the survey, and then the average of the daughters of the last proved sire listed. Brief information on herd conditions is also shown. At the bottom of the table is a summary of the number of lines that carry two or more consecutive crosses of proved sires. In the herd shown there are 5 female lines of descent with 3 successive crosses of proved sires—in this case, a cross of each of the proved sires used in the herd—and 11 lines with 2 crosses of proved sires. This number of female lines with successive crosses of proved sires is a check on the progress that has been made in the herd with proved-sire matings. In some herds where as many as 12 sires that had a sufficient number of daughter-dam pairs to be analyzed have been used, there were no female lines with more than four successive crosses of proved sires. Such herds have made no greater progress in piling up a superior inheritance through the continued use of proved sires for generation after generation than the herd that has used only four proved sires but used them in such a way that all of them appear in several female lines of descent. A comparison of the number of successive crosses of proved sires in the female lines of descent with the total number of proved sires is a good check on the progress made.

Discussion and Analysis of the Data Developed from the Survey

THE marshaling of production information on such a vast array of animals provides material the analysis of which should reveal certain facts regarding the progress made in breeding for better production under the practices that have prevailed in the herds covered by the survey. Of the total of 1,097 herds listed, only 708 are included in this final summary. Some of the returns were received too late to be included; others were omitted because they showed no evidence of progress. The omission of the latter group tends to distort the data somewhat, but the time allotted for the completion of the task necessitated this action.

Shortage of time further limited the scope of this final analysis, making it impossible to deal separately with the two measures of production, milk and percentage of fat. Butterfat production has long been accepted by breeders as a fair measure of producing ability, and it is a composite of milk production and percentage of butterfat. For this reason, the figures in this final summary deal only with pounds of butterfat produced.

ANALYSIS AND DISTRIBUTION OF THE AVERAGE BUTTERFAT PRODUCTION

These 708 herds are in 40 States, and seven breeds are represented. Records on 42,799 cows were submitted, which averaged 447 pounds of butterfat. Each herd averaged 60 records. Table 3 shows the distribution of these herds by breeds.

TABLE 3.—*Distribution of herds by breeds*

Breed	States	Herds	Total records	Average number of record per herd	Average butterfat production per cow
	Number	*Number*	*Number*	*Number*	*Pounds*
Ayrshire	10	27	2,355	87	369
Brown Swiss	3	5	163	33	395
Guernsey	28	121	5,839	48	442
Holstein-Friesian	37	366	23,624	65	462
Jersey	34	181	10,443	58	438
Red Polled	2	2	145	77	381
Shorthorn	2	6	230	38	349
Total or average		708	42,799	60	447

These records were all calculated to a mature-equivalent basis. The procedure in using other correction factors varied in different States. Some records were corrected for length of the lactation period, either to a full 365-day basis or to a 305-day basis; while in many cases no adjustment was made for this variable. In the routine analysis procedure short-time records were not considered. The number of milkings per day was standardized to a three-times-daily basis in some herds and to two milkings daily in others; although some herds reported records on cows milked two, three, and even

four times daily with no correction. The number of daily milkings seemed to depend largely on whether the testing was official testing or testing by a dairy herd-improvement association. Standard breed practice was also an influence.

There was no way to determine accurately the length of time that had elapsed during the period covered by the records submitted from each herd. However, there is a wide difference in the time span from the foundation cows to the daughters of the last sire. In most cases, this represented the entire period of the continuous keeping of production records, but the variation in the length of this period is easily understood when one herd reports on 2 sires and another on 10 or more.

To measure the progress made, the foundation cows were considered as the base. Seven hundred and eight herds reported records on an average of 15 foundation cows, averaging 436 pounds of butterfat. Forty-five other cows completed records during the period covered by the survey and averaged 451 pounds of butterfat. This made a cumulative herd average (previously defined) of 447 pounds of butterfat, just 11 pounds higher than the average of the foundation cows. These 45 records were made by daughters of the various herd sires used. It is a generally accepted fact that the introduction of regular testing into the herd management usually results in better general herd practices, such as feeding according to production, watering in the barn, supplementing pasture grass, etc. How much of this increase in herd average is due to better environmental conditions we are not prepared to say, but surely it has its influence.

Table 4 sets forth the averages of foundation cows and animals bred in the herd, and the final cumulative herd average by breeds.

TABLE 4.—*Numbers and average butterfat production of foundation cows, additions to the herd, and all tested cows*

Breed	Herds	Foundation cows		Additions to the herd		All tested cows		Increase (+) or decrease (−) in average butterfat production, foundation cows to all tested cows
		Total	Average butterfat production	Total	Average butterfat production	Total	Average butterfat production	
	Number	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Pounds*
Ayrshire	27	518	357	1,837	372	2,355	369	+12
Brown Swiss	5	51	425	112	381	163	395	−30
Guernsey	121	1,799	425	4,040	450	5,839	442	+17
Holstein-Friesian	366	6,163	448	17,461	467	23,624	462	+14
Jersey	181	2,393	435	8,050	439	10,443	438	+3
Red Polled	2	25	404	120	376	145	381	−23
Shorthorn	6	74	325	156	299	230	307	−18
Total	708	11,023	436	31,776	451	42,799	447	+11

The statistics on number of sires and their quality and distribution will be shown later.

From the 708 herds summarized above, 157 were selected as having shown progress in improving producing ability. These are designated as charted herds and the remaining 551 as uncharted herds. The satisfactory ratings of the sires used formed the basis on which the charted herds were selected; it is here that one would look to find the improvement that follows the use of good sires. The average number

of foundation cows in the charted herds was 17, with an average production of 447 pounds of butterfat. The additions, 62 cows bred in the herd, averaged 498 pounds of butterfat and made the cumulative herd average 487 pounds of butterfat, which is 40 pounds higher than that of the foundation cows. In comparison with the whole group, these herds had 2 more foundation cows, 17 more additions, and a total of 19 more animals with records. The foundation cows averaged 11 pounds more butterfat and the additions 47 pounds more, and the increase in the cumulative herd average was 40 pounds. Thus the charted herds were larger, used better sires, and bred better cows from foundation stock with a higher record. Table 5 gives the details by breeds.

TABLE 5.—*Numbers and average butterfat production of foundation cows, additions to the herd, and all tested cows in the charted herds*

Breed	Herds	Foundation cows		Additions to the herd		All tested cows		Increase in average butterfat production, foundation cows to all tested cows
		Total	Average butterfat production	Total	Average butterfat production	Total	Average butterfat production	
	Number	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Pounds*
Ayrshire	8	184	347	412	385	596	373	26
Guernsey	35	630	460	1,450	514	2,080	497	37
Holstein-Friesian	75	1,320	463	5,435	513	6,755	503	40
Jersey	39	521	426	2,490	475	3,011	466	40
Total or average	157	2,655	447	9,787	498	12,442	487	40

The remaining 551 uncharted herds were made up of an average of 15 foundation cows that averaged 433 pounds of butterfat and 40 additions that averaged 431 pounds of fat, and the cumulative herd average was 431 pounds of butterfat. Averages by breeds are given in table 6.

TABLE 6.—*Numbers and average butterfat production of foundation cows, additions to the herd, and all tested cows in the uncharted herds*

Breed	Herds	Foundation cows		Additions to the herd		All tested cows		Increase (+) or decrease (−) in average butterfat production, foundation cows to all tested cows
		Total	Average butterfat production	Total	Average butterfat production	Total	Average butterfat production	
	Number	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Pounds*
Ayrshire	19	334	363	1,425	369	1,759	368	+5
Brown Swiss	5	51	425	112	381	163	395	−30
Guernsey	86	1,169	406	2,590	415	3,759	412	+6
Holstein-Friesian	291	4,843	444	12,026	446	16,869	445	+1
Jersey	142	1,872	438	5,560	424	7,432	427	−11
Red Polled	2	25	404	120	376	145	381	−23
Shorthorn	2	74	325	156	299	230	307	−18
Total or average	551	8,368	433	21,989	431	30,357	431	−2

Here the effects of improved environment were apparently more than offset by the poor quality of the herd sires used, and a net loss of 2 pounds of butterfat resulted. It is striking that in the charted herds the average moved from 447 pounds for the foundation cows to 487 pounds, while in the uncharted herds it dropped from 433 pounds for the foundation cows to 431 pounds. Included in the uncharted group are the herds that had used only one proved bull, or the equivalent, and may have shown some progress from his use; yet 271 or approximately 50 percent of these herds had a cumulative herd average less than the average of the foundation cows.

These figures illustrate most strikingly how essential good sires are for breed progress. That only about 22 percent of the herds surveyed were selected for the charted group brings out the need for more thoughtful planning in our breeding herds, as this survey in itself was somewhat selective.

Sires in the Survey

The story of progress or decline in breeding for milk and butterfat is found in the analyses of the herd sires used in the 708 herds. Information was submitted on 4,309 sires, of which 2,242, or 52 percent, were proved by having five or more tested daughters from tested dams. The method of classifying these sires and the meaning of the classification is given elsewhere. The distribution of sires by breeds is given in table 7.

TABLE 7.—*Distribution of rated sires by breeds*

Breed	Herds	Sires	E		G		F		U		P		Total proved		NP	
	No.	*No.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*
Ayrshire	27	207	13	6.3	21	10.1	20	9.7	11	5.3	48	23.2	113	54.6	94	45.4
Brown Swiss	5	21	1	4.8	1	4.8	0	----	0	----	9	42.8	11	52.4	10	47.6
Guernsey	121	614	59	9.6	58	9.4	70	11.4	18	2.9	109	17.8	314	51.1	300	48.9
Holstein-Friesian	366	2,268	185	8.2	191	8.4	257	11.3	80	3.5	499	22.0	1,212	53.4	1,056	46.6
Jersey	181	1,160	87	7.5	89	7.7	106	9.1	41	3.5	243	21.0	566	48.8	594	51.2
Red Polled	2	10	1	10.0	0	----	0	----	0	----	8	80.0	9	90.0	1	10.0
Shorthorn	6	29	1	3.4	1	3.4	3	10.4	2	6.9	10	34.5	17	58.6	12	41.4
Total	708	4,309	347	8.0	361	8.4	456	10.6	152	3.5	926	21.5	2,242	52.0	2,067	48.0
Percentage of proved sires	----	----	15.5		16.1		20.3		6.8		41.3		----		----	

It is not possible to say precisely what effect the inclusion of the other 389 herds would have had on this distribution of sires, but it is well to bear in mind that at least some of these herds were omitted because they failed to show evidence of breeding progress, which means, of course, that they listed more poor than good herd sires. As table 7 stands, slightly over half of all the sires were proved and 52 percent of these proved sires rated E, G, and F; 6.8 percent were undeterminable and 41.3 percent were poor. On their composite showing as a group, the NP sires have a score of −13 points, which rates them undeterminable and only 2 points above the poor class. Only 27 percent of the total number of 4,309 sires rated E, G, and F, while 25 percent rated U and P.

The figures in table 8 indicate that the average herd reported on six sires, half of which were proved and half not proved. The 3

proved sires were mated to 33 dams that averaged 452 pounds of butterfat to get 33 daughters, which averaged 452 pounds of butterfat. The three NP sires were bred to six dams that averaged 452 pounds of butterfat, and their six daughters averaged 443 pounds of butterfat, a decrease of 9 pounds. The six sires had 39 daughters that averaged 451 pounds of butterfat from dams that averaged 452 pounds of butterfat. No gain here.

The comparative performance of sires of all classes is shown in table 8.

TABLE 8.—*Comparative performance of sires of all classes*

Class	Pairs of dams and daughters	Sires	Average butterfat production		Increase (+) or decrease (−) of daughters over dams		Daughters, better than dams	
			Daughters	Dams				
	Number	*Number*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Number*	*Percent*
E	3,608	347	506	414	+92	+22.2	2,960	82.0
G	4,171	361	487	445	+42	+9.4	2,761	66.2
F	5,510	456	472	461	+11	+2.4	3,045	55.3
U	1,980	152	449	459	−10	−2.2	931	47.0
P	10,086	926	409	463	−54	−11.7	2,984	29.6
Total proved	25,395	2,422	452	452	0	0	12,681	49.9
NP	4,203	2,067	443	452	−9	−2.0	1,981	47.1
	29,598	4,309	451	452	−1	−.2	14,662	49.5

The average production of the daughters of each grade of sires declines as the rating declines. There is a difference in the quality of the dam groups, but that is to be expected where the size of increase enters into the rating. The amount of increase and the percentage of daughters better than their dams are the bases on which the classifications are made.

The influence of the quality of sires on the selection of the 157 charted herds is best shown by the percentage of the total of each class which were used in these herds, as listed in table 9.

TABLE 9.—*Number of each class of sires in charted and uncharted herds*

Class	Total	Sires in 157 charted herds		Sires in 551 uncharted herds	
	Number	*Number*	*Percent*	*Number*	*Percent*
E	347	182	52.4	165	47.6
G	361	166	46.0	195	54.0
F	456	172	37.7	284	62.3
U	152	30	19.7	122	80.3
P	926	88	9.5	838	90.5
Total proved	2,242	638	28.5	1,604	71.5
NP	2,067	459	22.2	1,608	77.8
Total	4,309	1,097	25.5	3,212	74.5

While 25.5 percent of all sires were used in these 157 herds, they included 52.4, 46.0, and 37.7 percent, respectively, of all E, G, and F bulls and only 9.5 percent of all P bulls. Nearly 45 percent of the better bulls and less than 10 percent of the poor bulls were in service in the 22 percent of the herds which make up the charted group.

Dam and Daughter Comparisons

Dam and daughter comparisons for the groups as a whole have been given in table 8. To emphasize further the difference between the charted and uncharted herds, the dam and daughter information is divided on that basis as well as by breeds in table 10.

TABLE 10.—*Dam-daughter comparisons, by breeds, for charted and uncharted herds*

Herds	Herds	Proved sires	NP sires	Pairs	Average butterfat production of— Daughters	Average butterfat production of— Dams	Increase (+) or decrease (−) of daughters		Daughters better than their dams	
	Number	*Number*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Number*	*Percent*
AYRSHIRE										
Charted	8	28	19	375	383	363	+20	+5.5	219	58.4
Uncharted	19	85	75	1,360	368	385	−17	−4.4	578	42.5
Total or average	27	113	94	1,735	371	380	−9	−2.4	797	45.9
GUERNSEY										
Charted	35	107		1,342	513	478	+37	+7.7	842	62.7
Uncharted	86	207		2,457	418	420	−2	−0.5	1,183	48.1
Total or average	121	314		3,799	451	440	11	2.5	2,025	53.3
HOLSTEIN—FRIESIAN										
Charted	75	336	242	4,798	518	492	+26	+5.3	2,831	59.0
Uncharted	291	876	814	11,494	445	458	−13	−2.8	5,268	45.8
Total or average	366	1,212	1,056	16,292	467	468	−1	−0.2	8,099	
JERSEY										
Charted	39	167	139	2,213	478	450	+28	+6.2	1,325	59.9
Uncharted	142	399	455	5,197	425	441	−16	−3.6	2,286	44.0
Total or average	181	566	594	7,410	441	444	−3	−0.7	3,611	48.7
ALL BREEDS										
Charted				8,728	501	475		+5.5	5,217	59.8
Uncharted		1,604		20,870	430	413		−2.9	9,445	45.3
Total or average			2,067	29,598						

It is in table 10 that evidence is found of improvement due to breeding, that is, the influence of good herd sires. The figures in the table represent progress in a single generation. The previously mentioned 11-pound increase from the foundation to the final herd average spreads over a number of generations and is partly accounted for by improved environment. In the analysis of a single generation in table 10, the environmental influence is not so apt to be a large factor. Here it is found that the 29,598 daughters averaged 1 pound less than their dams, and that less than half were equal to or better than their dams. It is possible that to some extent this

result may be attributed to the practice in some herds of giving preference in replacements to daughters of dams with the higher records.

To bring out the story of the influence of better sires, the figures in the table are divided so as to show the results in the charted and uncharted herds. Briefly, the sires in the charted herds had 8,728 daughters averaging 501 pounds of butterfat from dams averaging 475 pounds of butterfat, an increase of 26 pounds, and about 60 percent were better producers than their dams. This contrasts with a decrease of 13 pounds for the 20,870 daughters in the uncharted herds dropped by dams averaging 443 pounds of butterfat, and only about 45 percent of the daughters better than their dams.

This becomes more significant when it is noted that the dams in the charted herds averaged 32 pounds more than the dams in the uncharted herds, and that the daughters in the charted herds averaged 71 pounds more butterfat than the daughters in the uncharted herds. The fact that the average sire's chances to increase production diminish as the average of the dams goes higher only adds to the proof that breeding is largely responsible for the showing made by the charted herds. If a single generation in the breeding of a herd means an average increase of 26 pounds of butterfat, with 12 daughters in 20 better than their dams, as contrasted with an average decrease of 13 pounds of butterfat, with 9 in 20 better, then it is well to give serious thought to the quality of herd sires used.

Sequence of Sires

With so much emphasis on the importance of herd sires, it might be well to explore this mass of data further.

The ideal, of course, is a continued sequence of good bulls to breed toward concentration of germ plasm for high production. Unfortunately, this ideal was seldom achieved in the herds under survey. Even some of the charted herds had set-backs from poor sires. Table 11 brings out the progress in the charted herds when arranged according to the number of proved sires used.

TABLE 11.—*Charted herds arranged by number of proved sires used*

Proved sires (number)	Herds	Foundation cows		Additions to the herd		All tested cows		Increase in average butterfat production, foundation cows to all tested cows
		Total	Average butterfat production	Total	Average butterfat production	Total	Average butterfat production	
	Number	*Number*	*Pounds*	*Number*	*Pounds*	*Number*	*Pounds*	*Pounds*
2	34	423	413	938	474	1, 361	455	42
3	49	726	440	2, 085	485	2, 811	473	33
4	27	473	443	1, 671	499	2, 144	487	44
5	17	260	451	1, 358	509	1, 618	500	49
6	10	131	427	863	485	994	477	50
7	6	149	498	497	537	646	528	30
8 and over	14	493	478	2, 375	508	2, 868	503	25
Total or average	157	2, 655	447	9, 787	498	12, 442	487	40

As the number of good sires increases, there is a steady building up of the cumulative herd average until the seven-sire group is reached. Here the number of herds is small and the percentage of U and P bulls is high enough to offset the expected advance. To have eliminated from the charted group all herds that had a P or U bull would have excluded most of the herds with long-established testing programs. Figures will show that the probability of a poor sire appearing in the average herd increases as time goes on. Another reason for the smaller increases in the last two groups is the high level of the foundation cows from which they come. The distribution and quality of the sires used in the herds in table 11 are shown in table 12.

TABLE 12.—*Charted herds arranged by number and distribution of proved sires*

Proved sires (number)	Herds	Total sires	E		G		F		U		P	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
2	34	68	29	42.7	24	35.3	15	22.0	0	------	0	------
3	49	147	46	31.3	43	29.3	44	29.9	8	5.4	6	4.1
4	27	108	37	34.3	25	23.1	29	26.9	4	3.7	13	12.0
5	17	85	29	34.1	21	24.7	18	21.2	6	7.1	11	12.9
6	10	60	10	16.7	15	25.0	17	28.3	6	10.0	12	20.0
7	6	42	9	21.4	7	16.7	18	42.8	1	2.4	7	16.7
8 and over	14	128	22	17.2	31	24.2	31	24.2	5	3.9	39	30.5
Total	157	638	182	28.5	166	26.0	172	27.0	30	4.7	88	13.8

An actuarial study of all the figures may help those engaged in the breeding of dairy cattle to get a picture of what actually happens, on the average, when they follow the breeding practices used in the 708 herds analyzed in this survey.[4] What, on the average, are the chances of having a poor bull follow a good one, or vice versa?

The figures show that if the last sire used was an E sire, there are about three chances in five the next one will be E, G, or F.

If the last sire used was P, there is only one chance in three that the next one will be E, G, or F, and two chances in three that he will be U or P.

If two E, G, or F sires have been used, there are apparently three chances in five that the next one will be E, G, or F.

If two P sires are used, the chances are two out of three that the next one will be a U or a P sire.

These averages indicate primarily the great chances—two to one—against getting a good sire when one or two poor ones have been used in the herd.

[4] Disregarding the appearance of NP sires in the line-up of bulls in the 708 herds, the following sequences are noted. 9 herds used only E sires, 7 only G sires, 7 only F sires, and 1 only U sires. Of these 24 herds, 21 were two-sire herds, 2 were three-sire herds, and the other was a four-sire herd. 90 herds had all P sires, 58 being two-sire herds; 23, three-sire herds; 5, four-sire herds; 3, five-sire herds; and 1, a six-sire herd. 28 herds used E and G sires, 28 others E and F sires, and 25 F and G sires. Of these 81 herds, 46 were two-sire herds, 34 were three-sire herds, 8 were four-sire herds, 2 were five-sire herds, and 1 was a six-sire herd. 16 other herds had only E, G, and F sires. 7 were three-sire herds, 4 were four-sire herds, 3 were five-sire herds, and 2 were seven-sire herds. 85 herds had 1 E, G, or F sire and 1 P sire. 20 herds had only E, G, [illegible]

1 of 6 P sires in the strings of sires.

In 36 herds the arrays of sires were sequences of alternating good and poor bulls and in 24 others the sequences were 2 good followed by 2 poor sires or vice versa.

To summarize this analysis and distribution of records in the 708 herds:

The information developed emphasizes the important part that good sires play in herd improvement.

The herds as a whole show improvement in cumulative herd average from foundation cows to the end of the survey period of only 11 pounds of butterfat. The charted herds show more than 3½ times as much improvement, or 40 pounds.

Comparison of nearly 30,000 dam-and-daughter pairs reveals that the daughters averaged 1 pound of butterfat less than their dams, and that 49½ percent were equal to or better than their dams as butterfat producers. Over 8,700 dam-and-daughter pairs in the 157 charted herds show an increase of 26 pounds of butterfat by the daughters, with nearly 60 percent exceeding their dams as producers. The dam-and-daughter comparison in the remaining 551 herds shows the daughters producing 13 pounds less butterfat than their dams, with about 55 percent poorer producers.

In this summary it is well to remind the reader that the herds surveyed average well above the production level of the dairy cow population, which is estimated to be 158 pounds of butterfat. Doubtless the testing program and general management in these herds had lifted them to a position above the general level. This position was achieved in part by selection of better breeding stock, but in a large measure it was due to more intelligent feeding, care, and culling. Yet regardless of how they reached their present state, the figures show that during the period covered by the survey only a part of these herds have made progress due to breeding. Some have held a fairly even level, but others have declined in inherent ability to produce milk and butterfat. If this reflects the conditions in selected herds, surely there is much need for thought and planning to improve the cow population as a whole.

The contrast between the charted and uncharted herds indicates the part breeding plays in raising producing ability.

AN EXAMPLE OF A HERD SUMMARY

Both time and space prevented the making of as complete a herd summary as was desired. Two types of herd summary have been prepared and described. The more complete herd summary for production has been described and illustrated on page 1024. This is the summary that is being returned to each cooperator. Had there been time for the greatly increased amount of work that would have been required for compilation, and had there been space for its publication for the herds showing progress, it would have been desirable to issue for each herd the type of summary illustrated in table 13. This summary is presented in order to show its possibilities for students of dairy-cattle breeding.

TABLE 13.—*Detailed herd summary*

RECORD OF FOUNDATION COWS AND THEIR DAUGHTERS

Foundation cows				Record of daughters of—											
				First proved sire, Majesty's Admiral, 172934				Second proved sire, Triple Hood Farm Torono, 270579				Third proved sire, Sophies Torono King George, 277122			
Cow no.	Butterfat	Production of—		Cow no.	Butterfat	Production of—		Cow no.	Butterfat	Production of—		Cow no.	Butterfat	Production of—	
		Milk	Butterfat			Milk	Butterfat			Milk	Butterfat			Milk	Butterfat
	Percent	*Pounds*	*Pounds*		*Percent*	*Pounds*	*Pounds*		*Percent*	*Pounds*	*Pounds*		*Percent*	*Pounds*	*Pounds*
288753	4.47	4,915	219	744510	5.59	4,441	248	945217	5.67	8,430	477	1026593	(1)		
				744514	5.16	6,938	358								
				751780	5.12	8,107	415	857873	5.31	8,166	434	979888	5.18	8,564	44
								Virginia B. C.	4.38	7,353	321				
								Maj. Mary Sue	4.40	7,834	344				
751779	5.63	4,657	262	781611	5.24	6,592	345					979887	5.50	9,342	51
												979890	5.03	9,999	50
												1026590	5.26	9,490	49
								857871	5.79	7,797	450	1026591	(1)		
Kate	3.49	12,485	436					Kate, Jr.	4.29	9,834	422				
Milcher	4.69	5,539	259	Milcher, Jr.	6.49	6,950	451	Mabel	5.31	9,054	481	Mazie	5.22	10,778	56
												Matina	(1)		
Spot	3.19	11,912	381	Blackie I	4.30	9,374	404								
				Blackie II	4.72	10,812	510								
536532	5.19	4,673	243	744511	4.99	7,301	365	843094[2]				979886	5.34	7,599	40
												979889	4.65	12,398	57
				744513	4.04	7,549	305					1026589	5.03	9,819	49
												943160	4.86	8,854	43
522815	4.43	5,887	261					852872	4.68	7,199	337				
Ziechiel	3.46	11,363	393					Ziechiel, Jr.	4.57	9,514	434	Zep	4.72	8,293	392
Armstrong	4.27	6,277	268	Blossom	4.30	8,589	369	Rose	4.52	11,342	512				
				Armstrong, Jr.	(1)			Isabelle	4.55	9,264	422				
693267	5.90	8,200	484					857874	4.60	7,774	358	979891	5.68	11,547	65
								934270	5.92	6,943	411	1026588	5.74	8,719	50
												1026601	5.66	9,639	54

[1] No record.
[2] Cow 843094 was by an unproved sire. Her record was 4.56 percent of butterfat, 8,348 pounds of milk, 376 pounds of butterfat.

TABLE 13.—*Detailed herd summary*—Continued

RECORD OF FOUNDATION COWS AND THEIR DAUGHTERS—Continued

Foundation cows				Record of daughters of—											
				First proved sire, Majesty's Admiral, 172934				Second proved sire, Triple Hood Farm Torono, 270579				Third proved sire, Sophies Torono King George, 277122			
Cow no.	Butter-fat	Production of—		Cow no.	Butter-fat	Production of—		Cow no.	Butter-fat	Production of—		Cow no.	Butter-fat	Production of—	
		Milk	Butter-fat			Milk	Butter-fat			Milk	Butter-fat			Milk	Butter-fat
	Percent	*Pounds*	*Pounds*		*Percent*	*Pounds*	*Pounds*		*Percent*	*Pounds*	*Pounds*		*Percent*	*Pounds*	*Pounds*
Green	4.92	6,880	339									Goldie	5.42	8,355	453
Hart	5.29	7,353	389					{Fannie	4.82	7,098	342	Faun	5.77	8,438	487
								{Helen	4.81	7,745	373				
Pearl	4.81	6,353	306									Perry	5.07	9,556	484
Nancy	4.09	7,656	313									Nancy	4.40	10,806	475
Elmo	4.59	4,756	218	Nillie	5.53	5,322	294								
Daughter dam pairs ... number					11	11	11		14	14	14		17	17	17
Average of daughters					5.04	7,452	369		4.93	8,292	407		5.21	9,541	495
Average of dams					4.59	6,262	269		5.12	7,596	376		4.92	7,695	375
Increase ... percent					9.8	19.0	37.2		−3.7	9.2	8.2		5.9	24.0	32.0
Daughters better ... do					63.6	72.7	100.0		57.1	64.3	64.3		64.7	88.2	88.2
Dam's record of herd average ... do					100.2	85.2	82.8		107.6	102.3	109.3		102.3	102.1	102.5
Rating of sire					G	G	E		F	G	G		G	E	E
Daughters tested ... percent					91.7	91.7	91.7		100	100	100		100	100	100
Milkings ... number				2				2				2			

Remarks: Grain fed 1:4, clover hay, silage, and pasture.

Table 13.—*Detailed herd summary*—Continued

4 FEMALE LINES WITH 3 SUCCESSIVE PROVED SIRE CROSSES

Butterfat production of—			
Foundation cows	Daughters of first proved sire cross	Daugthors of second proved sire cross	Daughters of third proved sire cross
Pounds	*Pounds*	*Pounds*	*Pounds*
262	415	434	443
259	451	481	563
219	248	477	N. R.
259	451	481	N. R.
249. 7	391. 2	468. 2	503

12 FEMALE LINES WITH 2 SUCCESSIVE PROVED SIRE CROSSES

262	450	N. R.	---
262	415	321	---
262	345	513	---
262	345	503	---
262	345	499	---
243	305	430	---
393	434	392	---
268	369	512	---
268	N. R.	422	---
484	358	656	---
484	411	500	---
389	342	487	---
319. 8	374. 4	475. 9	---

DISTRIBUTION OF RECORDS OF BUTTERFAT PRODUCTION OF FOUNDATION COWS AND DAUGHTERS OF 3 PROVED SIRES

	200 to 249 pounds	250 to 299 pounds	300 to 349 pounds	350 to 399 pounds	400 to 449 pounds	450 to 499 pounds	500 to 549 pounds	550 to 599 pounds	600 to 649 pounds	650 to 699 pounds	Average pounds
Foundation cows	3	4	3	3	1	1	---	---	---	---	318
Daughters of sire 1	1	1	2	3	2	1	1	---	---	---	369
Daughters of sire 2	---	---	4	2	5	3	1	---	---	---	408
Daughters of sire 3		---	---	1	3	6	4	2	---	1	495

The upper part of the summary brings together the data gathered on the large cards illustrated on pages 1015 to 1019. The records for the foundation cows and the daughters of the various sires are arranged in such a manner as to permit following the direct female line of descent from left to right. The second section of the summary, directly under the first section, shows the essential data used in the summaries for rating the sires, omitting the results of the calculations that were included in the summaries returned to the cooperators.

Included in this summarization of the sires is the percentage of the daughters of each sire old enough to have completed records at the time of the survey and actually having records. This is for the purpose of showing the amount of selective testing that may have taken place. Selective testing, which means the omission of records of poor-producing animals, is likely to give an incorrect picture of any analysis of sire inheritance that may be made. Unfortunately this

important information was omitted from many of the herd reports in this survey. In the herd shown in table 13, only one of all the daughters of these three sires that were old enough for records at the time of the survey did not have a record.

The next division of the summary in table 13 shows the successive crosses of the sires used in the herd that had a sufficient number of daughter-dam pairs to be evaluated (proved), and the butterfat yield of each cow. These tabulations could be improved, when space permits, by entering the name or number of each cow beside her butterfat yield. For some studies it would be desirable to show the variables—percentage of butterfat and milk yield—for the cows in these direct female lines of descent. In the table showing the female lines for successive proved-sire crosses, the first sire cross may be composed of the daughters of sire 1 only, or it may include daughters of sires 2 and 3. In herds in which three or more proved sires have been used, the female lines showing only two proved-sire crosses may be represented by the daughters of more than one sire in the second sire cross. In the herd shown in table 13, all of the proved sires used were meritorious sires and in each case each generation by a meritorious proved sire shows an increase in average yield.

The last tabulation in the summary shows the distribution of the records of all the foundation cows and of all the daughters of each sire, according to size of the butterfat record as given for each group at the head of each column. This tabulation includes many animals that do not enter into the female lines showing successive crosses of proved sires, some of them representing only one proved-sire cross. It should be understood, too, that the daughters of sire 2 are not all out of daughters of sire 1, nor are the daughters of sire 3 all out of daughters of sire 2.

In a general way this table shows the trend of the level of production in the herd and the range in production found in the foundation cows and in the daughters of the various sires. In this herd, the lower levels of production are being eliminated with each successive cross of a meritorious sire and the upper limits are being pushed up, as is to be expected when meritorious proved sires are continuously used, thereby concentrating the germ plasm for higher levels of production. This is further emphasized by the following calculation: The foundation cows in the herd shown in table 13 had an average of 318 pounds of butterfat and 33 percent of these cows had records of 350 pounds or more of butterfat. Sixty-four percent of the daughters of sire 1, 73 percent of the daughters of sire 2, and 100 percent of the daughters of sire 3 had records of 350 pounds or more.

TABLE 14.—*Distribution chart of butterfat production for 3 and 2 successive proved-sire crosses*

	200 to 249 pounds	250 to 299 pounds	300 to 349 pounds	350 to 399 pounds	400 to 449 pounds	450 to 499 pounds	500 to 549 pounds	550 to 599 pounds	600 to 649 pounds	650 to 699 pounds
4 lines with 3-sire crosses:										
Foundation cows	1	3								
Daughters of sire 1	1				1	2				
Daughters of sire 2					1	3				
Daughters of sire 3					1			1		
12 lines with 2-sire crosses:										
Foundation cows	1	7		2		2				
Daughters of first cross			5	2	3	1				
Daughters of second cross			1	1	2	2	4			1

Similar distribution charts can be arranged to show the raising of the level of production in those female lines having two and three successive crosses of proved sires.

The distribution chart (table 14) is made for the female lines showing three and two successive proved-sire crosses in the herd shown in table 13. This shows even more strikingly the shift toward higher production levels with successive crosses. This is possibly due to the continued injection into the herd of superior germ plasm which replaced the hereditary factors that necessitate low levels of production and brought about combinations of factors that make possible high levels of production. Such a picture can be clearly and correctly seen only in a herd for which the environmental conditions have remained fairly constant and are such as to permit the animal that received an inheritance for a high level of production to produce up to her hereditary capacity.

INBREEDING

Time did not permit an analysis of the relationship of the sires used in the herds included in this survey. Such an analysis for the herds that have made progress in breeding superior germ plasm and for the herds that have failed to make progress might possibly disclose interesting and valuable information.

Students of dairy cattle-breeding will be interested in table 15, which gives a detailed herd summary of what is perhaps the most intensely inbred experimental dairy herd (*12*). The inbreeding has been for the most part to the first sire used, Johan Woodcrest Lad 11th. Fortunately for this experiment, this sire carried no factors for abnormal characters that would be intensified in his inbred progeny. Fortunately too, he possessed an inheritance for a high level of production. He was mated to grade Jersey, Guernsey, and Holstein cows, and was bred back to his own daughters. He was followed by his son, out of his own 75-percent inbred daughter. The granddam of this son was a grade cow. The son, 94–B, thus carries three direct crosses of Johan Woodcrest Lad 11th.

As the table shows, he was mated to some of the foundation cows, to the outbred and to the inbred daughters of his sire, and also back to his own daughters. His 10 daughters out of foundation cows average 654 pounds of butterfat and their dams 591; his 4 daughters out of the outbred daughters of his sire average 658 pounds and their dams 636; the 6 daughters out of inbred daughters of his sire average 608 pounds of butterfat and their dams 616 pounds; and, as the table shows, his own 9 inbred daughters average 591 pounds butterfat as compared to 608 for their dams. Evidently 94–B possessed an inheritance for a level of production that was fully as high as that of his sire, if not higher. There is evidence also that in his more intensely inbred matings, such as those with the inbred daughters of his sire, and with his own daughters, there was a tendency toward depressing the level of production.

TABLE 15.—*Summary of an intensely inbred experimental herd of grade Holsteins of the Bureau of Dairy Industry, Beltsville, Md.*

RECORD OF FOUNDATION COWS AND THEIR FEMALE DESCENDANTS

Foundation cows				Johan Woodcrest Lad 11th 103987, first proved sire				Johan Woodcrest Lad 11th 103987, inbred generation, second proved sire				94-B (87½ percent son of Johan Woodcrest Lad 11th), third proved sire				94-B (87½ percent son of Johan Woodcrest Lad 11th), inbred generation, fourth proved sire				26-B (75 percent son of 94-B), not registered, fifth proved sire				40-B (75 percent son of 94-B), not registered, sixth proved sire			
Cow no.	Butterfat	Production of—		Cow no.	Butterfat	Production of—		Cow no.	Butterfat	Production of—		Cow no.	Butterfat	Production of—		Cow no.	Butterfat	Production of—		Cow no.	Butterfat	Production of—		Cow no.	Butterfat	Production of—	
		Milk	Butterfat			Milk	Butterfat			Milk	Butterfat			Milk	Butterfat			Milk	Butterfat			Milk	Butterfat			Milk	Butterfat
	Pct.	Lbs.	Lbs		Pct.	Lbs.	Lbs.		Pct.	Lbs.	Lbs.		Pct.	Lbs.	Lbs.		Pct.	Lbs.	Lbs.		Pct.	Lbs.	Lbs.		Pct.	Lbs.	Lbs.
												A-20	3.51	14,551	511	A-36	3.50	20,800	728								
7	4.09	10,367	424	50	3.83	14,660	561									A-65	3.45	14,631	505								
				64	3.84	15,313	588					A-37	3.58	19,903	713												
												A-42	3.45	19,466	672					A-74	3.38	15,661	530				
				45	4.29	11,529	495																				
23	4.17	9,308	388	82	3.68	18,131	667	A-2	3.49	19,682	687	A-21	3.18	17,615	560	A-45	2.80	18,307	512								
												A-30	3.26	15,606	509									A-79	3.49	18,255	638
25	4.40	9,821	432	67	3.83	15,379	589																				
33	4.70	13,284	624	14	3.86	11,733	453													A-64	3.93	19,894	782				
34	4.76	7,036	335	88	4.30	16,728	719																				
20	4.23	6,350	269	63	3.24	11,213	363	94	3.17	19,930	632	A-28	3.57	15,405	550												
								97	3.09	17,033	526																
								A-11	3.28	17,423	571									A-62	3.15	17,860	563				
18	5.36	8,919	478	46	4.46	10,196	455	79	4.44	9,691	430																
29	4.18	17,416	728	51	3.78	19,072	721	87	3.66	17,325	634																
								A-3	3.61	17,106	618	A-26	3.36	25,434	855									A-80	3.28	18,243	598
												A-58	3.36	17,356	582												
84	4.79	11,219	537									A-39	3.61	16,818	607					A-72	3.52	17,035	600				
																								A-83	3.54	17,198	608
												A-44	3.43	21,424	735					A-71	3.51	18,400	646				
												A-27	3.99	18,853	752	A-43	3.58	20,928	750	A-66	3.41	18,301	624				
93	4.81	13,686	658																					A-88	3.36	17,439	586
												A-46	3.99	16,092	642					A-67	4.10	16,381	672				
A-6	3.96	14,232	564									A-15	3.40	15,416	524	A-50	3.61	12,881	466								
																A-51	3.36	17,378	585								
A-7	4.35	16,461	716									A-32	3.28	19,229	631	A-47	3.36	14,492	487					A-81	3.67	13,075	480
A-29	4.23	12,502	516									A-48	3.97	14,966	595					A-69	3.35	15,256	511				
												A-57	3.52	18,275	644									A-85	3.51	12,644	444

A-13	3.93	16,934	666									A-40	3.88	21,245	824									A-84	3.46	18,718	648
												A-19	3.34	22,089	738	A-53	3.57	20,072	717								
21	4.56	15,647	714	91	3.91	19,926	779	A-9	3.52	15,241	536	A-38	3.23	13,906	449	A-52	3.52	15,113	568								
												A-25	3.38	21,394	723					A-59	3.44	17,193	592				
																								A-78	3.46	15,223	527
A-55	3.48	21,135	736																	A-75	3.29	23,343	768				
Daughter-dam pairs number					11	11	11		8	8	8		20	20	20		9	9	9		10	10	10		8	8	8
Average of daughters					3.91	14,898	581		3.53	16,679	579		3.51	18,252	641		3.42	17,178	591		3.51	17,932	629		3.47	16,349	566
Average of dams					4.43	10,711	473		3.65	15,732	574		4.05	15,320	607		3.44	17,679	608		3.60	18,138	648		3.55	18,476	655
Increase percent					−11.7	39.1	22.8		−3.3	6.0	0.9		−13.3	19.1	5.6		−0.6	−2.8	−2.8		−2.5	−1.1	−2.9		−2.3	−11.5	−13.6
Daughters better do					9.1	90.9	72.7		12.5	50.0	50.0		5.0	75.0	55.0		44.4	55.6	22.2		40.0	60.0	30.0		37.5	37.5	25.0
Dams records of herd average percent					101.1	83.9	86.2		87.1	115.4	102.1		100.2	106.9	107.2		89.4	112.2	102.5		95.0	113.5	109.3		94.7	113.9	109.5
Rating					P	E	E		P	G	F		P	E	F		P	F	P		P	F	P		P	P	P
Daughters tested percent				100				100				100				100				100				100			
Milkings number				3				3				3				3				3				3			

Remarks: Alfalfa hay and corn silage with grain enough to meet requirements of Savage standard.

Table 15.—*Summary of an intensely inbred experimental herd of grade Holsteins of the Bureau of Dairy Industry, Beltsville, Md.*—Continued

7 FEMALE LINES WITH 4 SUCCESSIVE CROSSES OF PROVED SIRES

Butterfat production of—				
Foundation cows	Daughters of first proved sire cross	Daughters of second proved sire cross	Daughters of third proved sire cross	Daughters of fourth proved sire cross
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
388	667	687	560	512
388	667	687	509	638
728	721	618	855	598
269	363	526	571	563
714	779	536	723	568
714	779	536	723	592
714	779	536	723	527
559	679	589	666	571

8 FEMALE LINES WITH 3 SUCCESSIVE CROSSES OF PROVED SIRES

424	588	511	728	----------
424	588	511	505	----------
424	588	672	530	----------
269	363	632	550	----------
658	752	750	624	----------
716	631	487	480	----------
714	779	738	717	----------
714	779	536	449	----------
543	633	605	573	----------

13 FEMALE LINES WITH 2 SUCCESSIVE CROSSES OF PROVED SIRES

424	588	713	----------	----------
624	453	782	----------	----------
478	455	430	----------	----------
728	721	634	----------	----------
537	607	600	----------	----------
537	607	608	----------	----------
537	735	646	----------	----------
658	752	586	----------	----------
658	642	672	----------	----------
564	524	466	----------	----------
564	524	585	----------	----------
516	595	511	----------	----------
516	644	444	----------	----------
565	604	591	----------	----------

DISTRIBUTION OF BUTTERFAT RECORDS OF FOUNDATION COWS AND DAUGHTERS OF 6 PROVED SIRES

	to poun	o 44 unds	50 to poun	600 to 649 pounds	650 to 699 pounds	700 to 749 pounds	750 to 799 pounds	800 to 849 pounds	850 to 899 pounds	Average (pounds)
Foundation cows				1	2	4	----	----	----	549
Daughters of first proved sire—Johan Woodcrest Lad 11th				0	1	2	1	----	----	581
Daughters (inbred) of second proved sire—Johan Woodcrest Lad 11th				3	1	---	---	----	----	579
Daughters of third proved sire—94-B (87½ percent son of first proved sire)				4	1	4	1	1	1	641
Daughters (inbred) of fourth proved sire—94-B				---	----	1	2	----	----	591
Daughters of fifth proved sire (75 percent son of 94-B)				3	1	----	2	----	----	629
Daughters of sixth proved sire (75 percent son of 94-B)				3	----	---	----	----	----	566

Sire 94–B has been followed in the herd by two of his inbred sons. The inbred son 26–B appears to have an inheritance for a higher level of production than does the inbred son 40–B. This raises the interesting question whether the lowering of production of the daughters of sire 40–B is due to his having inherited a lower level of production, or to the depressing influence of close inbreeding.

In the part of table 15 that shows the distribution of records of the foundation cows and of the daughters of six proved sires, it should be noted that where a sire was bred back to his own daughters this inbred generation is shown as another proved-sire generation. The table really shows the foundation cows; the outbred and the inbred daughters, separately, of Johan Woodcrest Lad 11th; the outbred and the inbred daughters, separately, of the sire 94–B; and the daughters of the two bulls 26–B and 40–B, neither of which has been mated to the other's daughters.

The foundation cows used in this experiment had an average butterfat yield of 549 pounds. The percentage of the foundation cows, and of the daughters of the various sires, that had records of 550 pounds of butterfat or above follows:

	Percent
Foundation cows	50
Daughters of sire 1, outbred	63
Daughters of sire 1, inbred	68
Daughters of sire 94–B, outbred	80
Daughters of sire 94–B, inbred	56
Daughters of sire 26–B	80
Daughters of sire 40–B	62

The terms outbred and inbred as used here simply differentiate between first-cross daughters and daughters bred back to the sire. As a matter of fact some of the daughters designated above as outbred daughters of 94–B were rather closely bred, being out of the outbred and inbred daughters of his sire, who was also, on the maternal side, his grandsire and great grandsire.

This tabulation shows a consistent elimination of the lower level records as the experiment proceeded, with the exceptions of the daughters that were the result of mating 94–B's daughters back to him, and the daughters of his inbred son 40–B.

On the whole the results of inbreeding in this experiment have been quite successful, owing largely to the fact that the first sire used, Johan Woodcrest Lad 11th, whose hereditary traits were concentrated in the succeeding generations, possessed excellent germ plasm for producing capacity and was free of factors for lethal traits, lack of fertility, and other abnormal characters. A similar experiment, concentrating the inheritance of a sire possessing inferior germ plasm, would have very different and less favorable results.

SIRE WITH AN INHERITANCE FOR LEVEL OF PRODUCTION BELOW THAT OF THE HERD

What happens when a sire is mated to dams with a much higher level of production than that governed by his own inheritance? How much lower producers will his daughters be? The answer will be different for different sires and different dams. If the dams have a concentration of germ plasm for the level expressed by their records, it is not likely that one cross of a sire whose inheritance is considerably

lower will send the production to very low levels. More than one cross of such sires would probably bring about a much lower level of production. If this poor sire is followed by a sire with an inheritance for a high level of production, the production may again approach its former level, though it will probably take more than one cross of such good sires to eliminate from the germ plasm any determiners for low levels of production that the poor sire injected.

Table 16 shows a herd with a high level of production in which one sire was used that possessed an inheritance for a level of production considerably lower than the records of the dams with which he was mated. The table shows female lines by consecutive crosses of the sires used in the herd, each figure for butterfat yield indicating an individual female in the line of descent. The distribution of the records of the daughters of each sire is also shown.

TABLE 16.—*Example of a herd with 1 sire possessing inheritance for lower butterfat production levels than the record of dams*

6 FEMALE LINES WITH 3 SUCCESSIVE PROVED-SIRE CROSSES

Butterfat production of—			
Foundation cows	Daughters of first sire cross	Daughters of second sire cross	Daughters of third sire cross
Pounds	*Pounds*	*Pounds*	*Pounds*
729	[1] 1,116	[1] 960	[2] 985
729	[1] 1,116	[3] 918	([4])
778	[1] 1,028	[3] 1,091	[2] 966
778	[1] 1,028	[3] 905	[2] 929
778	[1] 746	[3] 733	[2] 821
751	[1] 952	[3] 963	[2] 741
757	995	928	888

4 FEMALE LINES WITH 2 SUCCESSIVE PROVED-SIRE CROSSES

1,214	[3] 791	[2] 1,001	----------
1,214	[3] 791	[2] 967	----------
1,214	[3] 791	([4])	----------
729	[1] 1,116	[3] 918	----------
1,093	872	962	----------

DISTRIBUTION OF BUTTERFAT RECORDS OF FOUNDATION COWS AND DAUGHTERS OF 3 PROVED SIRES

	650 to 699 pounds	700 to 749 pounds	750 to 799 pounds	800 to 849 pounds	850 to 899 pounds	900 to 949 pounds	950 to 999 pounds	1,000 to 1,049 pounds	1,050 to 1,099 pounds	1,100 to 1,149 pounds	A (p
Foundation cows	------	2	2	------	------	------	------	------	------	1	824
Daughters of sire 1	------	1	------	------	------	------	3	1	------	1	962
Daughters of sire 2	------	1	2	1	------	2	1	------	1	------	878
Daughters of sire 3	------	1	------	1	------	2	4	1	------	------	918

[1] By sire 1.
[2] By sire 3.
[3] By sire 2.
[4] No record.

The sire with the inheritance lower than that of the dams with which he was mated was the second of the three sires used in the herd. He was mated to extraordinarily high producing cows. In

the distribution showing female lines with three and two crosses of proved sires, sire 2 has six daughters out of daughters of sire 1, and one foundation cow. The six dams averaged 1,029 pounds of butterfat and the daughters 902, a decline of 12 percent. Two of the six daughters were better than their dams. Sire 3, rated a better sire than sire 2, has five daughters whose dams were daughters of sire 2. The daughters averaged 899 of butterfat and the dams 874, an increase of less than 3 percent. Three of the daughters of sire 3 were better than their dams and they were out of the lower producing daughters of sire 2. These five daughters of sire 3 that were out of daughters of sire 2 are lower producers on the average than the remainder of his daughters. To what extent is the high production of the daughters of sire 2 due to the inheritance they received from their dams? Only a breeding test of sire 2 on lower producing dams would definitely settle the question.

Perhaps the effect of sire 2 is shown more clearly by showing the percentage of the foundation cows and of the daughters of each sire that had records of 800 pounds of butterfat or better.

20 percent of foundation cows.
83 percent of daughters of sire 1.
62 percent of daughters of sire 2.
89 percent of daughters of sire 3.

Tables 17 and 18 show distributions for two herds where two good sires were used followed by a poor sire. The first two sires used in the herd for which data are shown in table 17 were rated F, E, E and F, G, G; the third sire was F, P, P. Note how the production increased with each succeeding cross of the meritorious sires and dropped with the succeeding cross of the poor sire; and in the distribution table for all records of foundation cows, and the three sires, observe how the lower ranges of production were eliminated and the upper ranges raised with the first two sires, and how the lower ranges were returned in the progeny of the third sire. The same story is told in the herd for which data are shown in table 18.

TABLE 17.—*Example of butterfat production in a herd with 2 good sires followed by a poor sire*

2 FEMALE LINES WITH 3 SUCCESSIVE PROVED-SIRE CROSSES

Butterfat production of—			
Foundation cows	Daughters of sire 1	Daughters of sire 2	Daughters of sire 3
Pounds	*Pounds*	*Pounds*	*Pounds*
244	415	501	(1)
(1)	378	507	(1)
244	397	504	(1)

8 FEMALE LINES WITH 2 SUCCESSIVE PROVED-SIRE CROSSES

244	467	----------	313
244	415	----------	505
348	590	----------	270
348	383	463	----------
348	383	382	----------
367	----------	544	302
(1)	378	----------	248
(1)	378	----------	432
317	428	463	345

[1] No record.

Table 17.—*Example of butterfat production in a herd with 2 good sires followed by a poor sire*—Continued

DISTRIBUTION OF BUTTERFAT RECORDS OF FOUNDATION COWS AND DAUGHTERS OF 3 PROVED SIRES

	200 to 249 pounds	250 to 299 pounds	300 to 349 pounds	350 to 399 pounds	400 to 449 pounds	450 to 499 pounds	500 to 549 pounds	550 to 599 pounds	Average (pounds)
Foundation cows	1	----	2	1	--------	--------	--------	--------	325
Daughters of sire 1	--------	1	1	3	2	2	--------	1	408
Daughters of sire 2	--------	--------	--------	3	1	1	3	--------	445
Daughters of sire 3	2	1	2	--------	1	2	1	--------	361

Table 18.—*Another example of butterfat production in a herd with 2 good sires followed by a poor sire*

2 FEMALE LINES WITH 4 SUCCESSIVE PROVED-SIRE CROSSES

Butterfat production of—				
Foundation cows	Daughters of sire 1	Daughters of sire 2	Daughters of sire 1	Daughters of sire 3
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
407	526	428	425	252
407	526	428	425	396
407	526	428	425	324

5 FEMALE LINES WITH 3 SUCCESSIVE PROVED-SIRE CROSSES

244	325	393	----------	[1]
343	240	367	186	----------
407	526	428	----------	[1]
407	526	428	----------	342
407	526	----------	437	310
362	429	404	311	326

7 FEMALE LINES WITH 2 SUCCESSIVE PROVED-SIRE CROSSES

359	325	340	----------	----------
359	325	340	----------	----------
244	346	393	----------	----------
343	240	367	----------	----------
407	526	436	----------	----------
318	299	519	----------	----------
396	418	356	----------	----------
347	354	393	----------	----------

1 No record.

DISTRIBUTION OF BUTTERFAT RECORDS OF FOUNDATION COWS AND DAUGHTERS OF 3 PROVED SIRES

	Less than 200 pounds	200 to 249 pounds	250 to 299 pounds	300 to 349 pounds	350 to 399 pounds	400 to 449 pounds	450 to 499 pounds	500 to 549 pounds	Average (pounds)
Foundation cows	--------	2	2	2	1	1	1	--------	327
Daughters of sire 1	1	1	1	2	1	4	--------	2	377
Daughters of sire 2	--------	--------	--------	1	3	2	--------	2	421
Daughters of sire 3	--------	--------	1	2	4	--------	--------	--------	346

In these two herds, did the production drop back to lower levels because the dams to which they were mated had not approached homozygosity for the factors determining the higher levels of production and therefore did not tend to hold up the production of the daughters, or because the poor sires possessed an inheritance for much lower levels of production? Perhaps it was both, for in the herd shown in table 17 the foundation cows had records averaging 325 pounds of butterfat and only 25 percent had records of 350 pounds or more, while 80 percent of the daughters of sire 1, 100 percent of the daughters of sire 2, and only 44 percent of the daughters of sire 3 had records of 350 pounds or more. In the herd shown in table 18, the foundation cows averaged 327 pounds of butterfat and 33 percent of them had records of 350 pounds or more, while 58 percent of the daughters of sire 1, 87 percent of the daughters of sire 2, and 57 percent of the daughters of sire 3 had records above that level. Apparently sire 3, rating P, P, P, in the herd shown in table 18 did not carry many factors for as low levels of production as did sire 3, rating F, P, P, in the herd shown in table 17, providing the daughters of both sires had the same opportunity to produce up to their inherent capacity—a proviso that of course holds for all cases.

MAINTAINING HIGH PRODUCTION BY KEEPING ONLY THE HIGHER RECORD COWS FOR BREEDERS

It is apparent in the data resulting from this survey that in many herds the cows with the best records in each generation are the brood cows of the next generation of females and the poorer producers are culled from the herd. Very often the sires used have daughters that are consistently lower producers than the dams to which they are mated, yet the level of production is maintained by using only the better producing cows as breeders. With such practices, how rapidly will it be possible to eliminate the germ plasm that is responsible for the continual appearance of low producers in succeeding generations? The following tables are shown for herds that appear to illustrate the practice described.

In table 19 sire 2 has an inheritance for the highest level of production of the three sires. His daughters have the same average yield as those of sire 1, though he was mated to dams with much lower yields. It is apparent that sire 3 possessed an inheritance for a much lower level of production than either sire 1 or sire 2, though he was mated to cows with good yields. The dams to which sire 3 was mated have a higher average yield than do the daughters of sire 1 or sire 2, indicating that the higher producing cows had been kept for brood cows. The generations of females with successive crosses of these sires show a decline for each succeeding generation, with one exception where the numbers were limited. The distribution of the records of the daughters of the sires shows a tendency toward an increase in the lower levels of production.

TABLE 19.—*Example of the use of selected cows for breeding*

2 FEMALE LINES WITH 4 SUCCESSIVE PROVED-SIRE CROSSES

Butterfat production of—				
Foundation cows	Daughters of sire 1		Daughters of sire 2	Daughters of sire 3
	Outbred	Inbred		
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
458	374	283	389	345
458	374	283	422	387
458	374	283	405	366

5 FEMALE LINES WITH 3 SUCCESSIVE PROVED-SIRE CROSSES

432	365	------------	321	229
393	393	------------	430	196
393	393	------------	430	340
292	386	------------	323	335
458	374	283	389	----------
394	382	283	379	275

8 FEMALE LINES WITH 2 SUCCESSIVE PROVED-SIRE CROSSES

383	421	------------	336	----------
393	329	------------	317	----------
393	329	------------	386	----------
292	386	------------	------------	(1)
292	386	------------	(1)	----------
458	374	------------	345	----------
458	374	278	------------	----------
458	390	------------	------------	298
391	374	278	346	298

[1] No record.

DISTRIBUTION OF BUTTERFAT RECORDS OF FOUNDATION COWS AND DAUGHTERS OF 3 PROVED SIRES

	Less than 200 pounds	200 to 249 pounds	250 to 299 pounds	300 to 349 pounds	350 to 399 pounds	400 to 449 pounds	Average (pounds)
Foundation cows	----------	----------	1	----------	2	2	392
Daughters of sire 1	----------	----------	2	1	7	1	359
Daughters of sire 2	----------	----------	----------	6	2	2	359
Daughters of sire 3	1	1	2	3	3	----------	315

BUTTERFAT PRODUCTION DATA FOR THESE SIRES

	Sire 1, 11 daughter-dam pairs	Sire 2, 10 daughter-dam pairs	Sire 3, 10 daughter-dam pairs
Average butterfat yield of daughters........pounds..	359	359	315
Average butterfat yield of dams........do....	407	362	391
Decrease........percent..	11.8	.8	19.4
Daughters better than dams........do....	27.3	40.0	20.0
Rating........	P	P	P

In table 20 the daughters of sire 1 were better producers than their dams, while the daughters of sires 2 and 3 were not so good as their dams. The daughters of sires 2 and 3, however, had higher yields on the average than did those of sire 1, the dams to which they were mated having higher levels of production. The dams to which sire 2 was mated had a higher yield than did either the daughters of sire 1 or the dams to which he was mated. The same thing may be said of the dams to which sire 3 was mated with respect to either the daughters of sire 2 or sire 1, or the dams to which they were mated. The distribution section of the table shows that in this herd these higher producing dams must have had some influence in eliminating the lower levels of production, though this may be due in part to the inheritance possessed by sires 2 and 3. However, sire 1, a positively good sire, was more efficient in eliminating low production from the herd than either sire 2 or sire 3, though he was mated to dams whose records on the average were only 57 percent as high as those to which sire 3 was mated. This is shown by the following figures:

45 percent of the foundation cows had records of 350 pounds of fat or better.
70 percent of the daughters of sire 1 had records of 350 pounds of fat or better.
54 percent of the daughters of sire 2 had records of 350 pounds of fat or better.
66 percent of the daughters of sire 3 had records of 350 pounds of fat or better.

TABLE 20.—*Example of the use of selected cows for breeding*

3 FEMALE LINES WITH 3 SUCCESSIVE PROVED-SIRE CROSSES

Butterfat production of –				
Foundation cows	Daughters of sire 1	Daughters of sire 2		Daughters of sire 3
		Outbred	Inbred	
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
339	------	367	421	329
339	------	367	421	(1)
296	400	453	311	(1)
325	400	396	384	329

18 FEMALE LINES WITH 2 SUCCESSIVE PROVED-SIRE CROSSES

276	461	(1)	------	------
276	461	329	------	------
276	461	------	------	356
276	461	------	------	367
276	415	319	------	------
276	415	310	------	------
276	327	------	------	312
347	------	369	------	364
(1)	432	320	------	------
296	400	453	------	------
296	400	377	------	------
296	297	388	------	------
414	------	335	313	------
414	------	416	------	402
414	------	416	------	428
(1)	373	349	------	------
(1)	------	392	------	349
(1)	369	291	------	------
	406	[2] 362	[2] 313	[2] 368

[1] No record.
[2] Average of second cross, 361 pounds.

Table 20.—*Example of the use of selected cows for breeding*—Continued

DISTRIBUTION OF BUTTERFAT RECORDS OF FOUNDATION COWS AND DAUGHTERS OF 3 PROVED SIRES

	Less than 200 pounds	200 to 249 pounds	250 to 299 pounds	300 to 349 pounds	350 to 399 pounds	400 to 449 pounds	450 to 499 pounds	500 to 549 pounds	550 to 599 pounds	Average (pounds)
Foundation cows			4	2	2	1		1	1	372
Daughters of sire 1		1	1	1	3	3	1			366
Daughters of sire 2			1	8	5	5	1	1		365
Inbred daughters of sire 2				2		1				348
Daughters of sire 3				4	4	3	1			374

BUTTERFAT PRODUCTION DATA FOR THESE SIRES

	Sire 1, 7 daughter-dam pairs	Sire 2, 23 daughter-dam pairs	Sire 3, 12 daughter-dam pairs
Average butterfat yield of daughters ... pounds	356	370	374
Average butterfat yield of dams ... do	282	396	423
Increase (+) or decrease (−) ... percent	+26.2	−6.6	−11.6
Daughters better than dams ... do	85.7	43.5	16.7
Rating	E	P	P

The herd for which data are shown in table 21 apparently is one in which the better producing cows were kept in the herd and the lower producers culled out. In this herd the sires appear to have possessed an inheritance for level of production that was a great deal lower than the level of production of the dams to which they were mated as expressed by the dams' records. This is shown both in the female lines having two successive crosses of these sires and in the distribution of the records of the foundation cows and the daughters of the three sires, which shows a marked tendency for the production to shift to lower levels with each succeeding sire. This is further shown by the fact that 100 percent of the dams had records of 350 pounds of butterfat or better; 60 percent of the daughters of sire 1, 36 percent of the daughters of sire 2, and only 22 percent of the daughters of sire 3 had records of 350 pounds of butterfat or above.

Table 21.—*Example of the use of selected cows for breeding*

7 FEMALE LINES WITH 2 SUCCESSIVE CROSSES OF PROVED SIRES

Butterfat production of—		
Foundation cows	Daughters of first proved-sire cross	Daughters of second proved-sire cross
Pounds	*Pounds*	*Pounds*
397	316	345
501	334	277
493	432	375
493	432	205
376	414	227
458	367	(1)
360	(1)	270
440	383	283

[1] No record.

TABLE 21.—*Example of the use of selected cows for breeding*—Continued

DISTRIBUTION OF BUTTERFAT RECORDS OF FOUNDATION COWS AND ALL TESTED DAUGHTERS OF 3 PROVED SIRES

	200 to 249 pounds	250 to 299 pounds	300 to 349 pounds	350 to 399 pounds	400 to 449 pounds	450 to 499 pounds	500 to 549 pounds	Average (pounds)
Foundation cows				4	3	4	1	435
Daughters of first proved sire			2	1	2			373
Daughters of second proved sire		2	7	5				336
Daughters of third proved sire	3	2	2	1	1			291

BUTTERFAT PRODUCTION DATA FOR THESE SIRES

	Sire 1, 5 daughter-dam pairs	Sire 2, 13 daughter-dam pairs	Sire 3, 9 daughter-dam pairs
Average butterfat yield of daughters ... pounds	373	347	291
Average butterfat yield of dams ... do	435	409	409
Decrease ... percent	14.3	16.6	28.9
Daughters better than dams ... do	20.0	38.5	11.1
Rating	P	P	P

These illustrations indicate that even though the production level is maintained, or nearly maintained, by the constant selection of the higher producing cows for brood cows and the culling of the poor producing cows from the herd, there will be but little diminution in the number of cows with poor germ plasm in the later generations, and there will be a continual need to cull these cows from the herd unless the sires used possess an inheritance for superior levels of production. If the sires used possess an inheritance for level of production that is markedly lower than the dams, the proportion of cows with poor germ plasm will rapidly increase even when only the higher producers are kept for brood cows. As further evidence of this, note how quickly the superior producing ability of the granddams is leveled in the daughters and granddaughters by one or two crosses of sires with inferior germ plasm.

RESULTS WITH GOOD SIRES AND NO SELECTION OF THE BROOD COWS

In the experimental breeding herds of the Bureau of Dairy Industry it has been the practice to keep every cow in the herd till she has a heifer, if at all possible, and to test every cow under as nearly equal environmental conditions as possible, regardless of her producing capacity. In the field-station herds all animals are given an opportunity to make a record as 2-year-olds, or with first calf, to be used in inheritance studies. During this lactation they are milked three times a day throughout the year; they are fed rations consisting of grain mixtures, alfalfa hay, and corn silage that are kept as uniform as possible year after year. Therefore these herds represent a minimum of selection on the female side. The only selection occurs when the herd gets too large, and then the oldest and most unsound cows are removed. There is some natural selection resulting from sterility or failure to produce heifer calves on the one hand, or from producing a preponderance of heifer calves on the other hand.

The figures on one of these field-station herds, at Huntley, Mont., are shown in table 22. This offers the best material available for answering the question, "What results will follow when there is no selection in the females and good sires are used?"

Table 22.—*Example of a herd in which no selection is practiced*

2 FEMALE LINES WITH 4 SUCCESSIVE PROVED-SIRE CROSSES

Butterfat production of—					
Foundation cows	Daughters of sire 1	Daughters of sire 2	Daughters of sire 3	Daughters of sire 4	Daughters of sire 5
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
372	645	684	517		638
444	618	658	707		624
408	632	671	612		631

9 FEMALE LINES WITH 3 SUCCESSIVE PROVED-SIRE CROSSES

372	645	685	753		
701	591	675	747		
444	618	658			580
626	822	550	303		
626	822	616			586
626		668		616	677
626		668	702		679
623	730			655	674
623		661	544	622	
585	705	648	610	631	639

10 FEMALE LINES WITH 2 SUCCESSIVE PROVED-SIRE CROSSES

565	569	390			
597	560				675
701	591	430			
565	569		663		
626	822	550			
626	736		496		(1)
626	736		496		(1)
531	668		460		
623	730	448			
623	730				715
608	671	455	529		695

[1] No record.

DISTRIBUTION OF BUTTERFAT RECORDS OF FOUNDATION COWS AND DAUGHTERS OF 5 PROVED SIRES

	200 to 249 pounds	250 to 299 pounds	300 to 349 pounds	350 to 399 pounds	400 to 449 pounds	450 to 499 pounds	500 to 549 pounds	550 to 599 pounds	600 to 649 pounds	650 to 699 pounds	700 to 749 pounds	750 to 799 pounds	800 to 849 pounds	Average (pounds)
Foundation cows				1	1		2	4	3	1	2		1	598
Daughters of sire 1								4	4	7	2		1	658
Daughters of sire 2				1	2		1	1	2	7				589
Daughters of sire 3			1			2	2			2	3	1		595
Daughters of sire 4							1		2	1				605
Daughters of sire 5								2	2	4	1	1		663

SUMMARY OF BUTTERFAT PRODUCTION

	Sire 1, 18 daughter-dam pairs	Sire 2, 14 daughter-dam pairs	Sire 3, 11 daughter-dam pairs	Sire 4, 4 daughter-dam pairs	Sire 5, 10 daughter-dam pairs
Daughters ..... pounds	658	589	595	605	663
Dams ..... do	580	653	661	624	648
Increase (+) or decrease (−) ..... percent	+13.5	−9.8	−10.0	−3.0	+2.3
Daughters better than dams ..... do	83.5	57.1	45.5	25.0	50.0
Rating	G	P	P	NP	F

The first sire used in the herd at the Huntley Station was untried, but the records of his daughters in the herd indicated that he had an inheritance that appeared highly concentrated for a very high level of production. An interesting feature of this bull's proving is that after a large proportion of the Huntley Station herd was made up of his daughters, he was used for a time in a farmer's herd of grade cows (see the record of his transmitting ability in that herd in tables 26 and 28 under sire no. H104), and later he was moved to another station herd, where he continued in service to the age of 16 years. Thus he was used in three different herds, in each of which were females of entirely different lines of breeding. In each herd his daughters were much better producers than their dams.

Sire 2 was bred in one of the Bureau of Dairy Industry herds and proved out in a farmer's herd, where his 15 daughters were uniformly better than their dams. (See the record of A105 in table 26.) Sire 3 was purchased because of the very high yield of his daughters and because of the splendid increase in production of his daughters over their dams. He was used for a time in the Huntley Station herd and later in the experiment station herd at Beltsville, Md. In both of these herds he showed the same marked peculiarity in his transmitting ability for production. Approximately 75 percent of his daughters in these two herds were high-producing cows and the remaining 25 percent were very disappointing as producers.

There was such a great difference between the producing capacity of his good daughters and that of his poor daughters that we were led to question whether the poor daughters were low because they had received an inheritance for low production from their parents or because of some physiological weakness that made it impossible for them to express what was believed to be their inherited capacity.

E. I. Evans, of the Bureau of Dairy Industry, was then experimenting with the lactation-stimulating principle secured from the anterior pituitary gland. Some of the extract was injected into the poor-producing daughters of this sire. Most of them responded with an increase of 25 to 50 percent in milk flow, though the increased flow was not maintained after the injections were discontinued. The higher producing daughters did not respond with an increase in production. It thus appears that the poor-producing daughters of this particular sire are probably low producers because of a deficiency in the secretion of some necessary principle from the anterior pituitary. Daughters of these lower producing cows by other sires appear to be producing normally.

In the female lines with three successive crosses of proved sires shown in table 23, the lowest producing daughter of sire 3 has a record of 303 pounds of butterfat. This cow has a daughter by sire 5 that is now on test as a 2-year-old and has produced 315 pounds of butterfat in 6 months. In the female lines with two successive crosses of proved sires, the daughter of sire 3 with a record of 496 pounds of butterfat has a daughter by sire 5 on test as a 2-year-old that has produced 534 pounds of butterfat in 345 days. When completed and corrected for difference in age, the records of both these heifers will greatly exceed those of their dams and will be comparable to the records of other daughters of sire 5.

Sire 4 was selected on the basis of the excellent production of his daughters and their superior producing ability as compared to that of their dams in the herd in which he was used. Unfortunately he

was never a sure breeder in the station herd at Huntley and only a small number of daughters were secured.

Sire 5 was also selected because of the superior producing ability of his daughters. The final record of the producing ability of this sire's daughters in four different herds, as shown at the time of these surveys, is given in table 27. Since not all of the daughters of either sire 4 or sire 5 are old enough to have completed records, the story is incomplete.

There have been a few daughters of sires 2 and 3 in the lower groups, but in general the level of production has been upward. This is partly shown by the percentage of records of 600 pounds of butterfat or better for the various groups. These percentages are: Foundation cows, 46.3 percent; daughters of sire 1, 77.7 percent; daughters of sire 2, 64.3 percent; daughters of sire 3, 54.5 percent; daughters of sire 4, 75 percent; and daughters of sire 5, 80 percent.

Only two of the five sires, when judged by the comparison of their daughters and dams in the Huntley Station herd, can be said positively to possess an inheritance for level of production as high as or higher than that of the dams to which they were mated. Sires 2 and 4 were quite adequately proved in other herds, though on cows with lower levels of production than the cows with which they were mated in the Huntley Station herd. Their transmitting abilities in these herds indicate that they did possess an inheritance for good levels of production, even though it was below that of the high record cows in the station herd.

It appears from the records of this herd that progress can be made without culling in the female line if sires with the right kind of germ plasm are used.

WHAT ARE THE RESULTS WHEN POOR SIRES ARE USED AND THERE IS NO SELECTION IN THE BROOD COWS?

Examples have been discussed of the effects of mating sires to high-producing dams where the sire's inheritance for level of production was apparently below the levels of the dams; of the effects where a series of poor sires are used in a herd but where apparently only the higher producing cows are kept for brood cows, the lower producing cows being culled from the herd; and of the effects where a series of good sires are used in a herd and no selection is made in the females to be used as brood cows. Another part of the picture is the result when a series of poor sires are used and no selection or culling takes place among the dams.

It is difficult to know definitely from the data presented in this survey that there has not been selection practiced in choosing the higher producing cows for brood cows. The fact that 100 percent of the daughters of the sires that are old enough to have records actually have been tested does not necessarily prove that selection has not taken place in the brood cows. In fact it is necessary to have the records before selection can be made intelligently. The only guide, without the actual facts, is that the dams to which succeeding sires are mated fall somewhere within the range of the dams and daughters of the sire used in the preceding generation. This measure appears to apply to the herd whose figures are shown in table 23, though the female lines with successive crosses indicate that some of these sires were used concurrently.

Table 23.—*Example of a herd in which no selection is practiced*

2 FEMALE LINES WITH 3 SUCCESSIVE PROVED-SIRE CROSSES

Butterfat production of—					
Foundation cows	Daughters of sire 1	Daughters of sire 2	Daughters of sire 1	Daughters of sire 3	Daughters of sire 4
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
(1)	----------	303	252	237	----------
361	----------	281	----------	245	298
361	----------	292	252	241	298

[1] No record.

18 FEMALE LINES WITH 2 SUCCESSIVE PROVED-SIRE CROSSES

393	462	253	----------	----------	----------
325	218	----------	----------	----------	355
325	218	----------	----------	----------	307
325	218	----------	----------	----------	263
333	238	----------	----------	246	----------
333	238	----------	----------	----------	199
361	----------	281	----------	273	----------
361	----------	281			
		[1] 309	----------	----------	----------
268	----------	227	----------	274	----------
268	----------	227	----------	----------	187
359	----------	213	----------	----------	178
347	----------	----------	----------	251	222
229	----------	254	----------	----------	191
229	----------	254	----------	----------	262
229	----------	208	----------	220	----------
229	----------	208	----------	----------	267
323	----------	----------	----------	266	291
290	----------	----------	----------	289	197
307	265	271	----------	260	243

[1] An inbred daughter of sire 2 out of the cow above.

DISTRIBUTION OF BUTTERFAT RECORDS OF FOUNDATION COWS AND DAUGHTERS OF 4 PROVED SIRES

	Less than 200 pounds	200 to 249 pounds	250 to 299 pounds	300 to 349 pounds	350 to 399 pounds	400 to 449 pounds	450 to 499 pounds	Average (pounds)
Foundation cows	----	1	4	5	6	1	2	344
Daughters of sire 1	----	2	1	----	1	----	1	309
Daughters of sire 2	3	4	4	4	1	----	----	253
Daughters of sire 3	1	6	8	3	----	----	----	262
Daughters of sire 4	6	2	9	1	1	----	----	248

SUMMARY OF BUTTERFAT PRODUCTION FOR THESE SIRES

	Sire 1, 5 daughter-dam pairs	Sire 2, 13 daughter-dam pairs	Sire 3, 16 daughter-dam pairs	Sire 4, 19 daughter-dam pairs
Daughters .... pounds	309	255	257	248
Dams .... do	367	342	311	274
Decrease .... percent	58	87	54	26
Daughters better than dams .... do	10.0	23.1	16.7	42.1
Rating	P	P	P	P

There are only two female lines with as many as three successive crosses of the four sires analyzed. The numbers are too small to be significant, but the averages that follow do show a downward trend—foundation cows, 361 pounds of butterfat, first-sire cross 292 pounds,

second-sire cross 297 pounds, and third-sire cross 267 pounds. The 18 female lines with two successive crosses are more indicative of the trend because of the greater numbers, the averages being—foundation cows 307 pounds of butterfat, first-sire cross 253 pounds, and second-sire cross 250 pounds. The first- and second-sire crosses leveled out when around the 250-pound mark.

The distribution of records is interesting in that it shows the influence of the higher record dams to which sires 1 and 2 were mated. Sires 3 and 4 were mated to lower record dams, particularly sire 4, and there was a marked tendency for all daughters to trend toward lower levels, as is shown by the following calculations:

Percentage of foundation cows and daughters of sires with records of 350 pounds of butterfat or better

	Percent
Foundation cows	47.4
Daughters of sire 1	40.0
Daughters of sire 2	6.3
Daughters of sire 3	0.0
Daughters of sire 4	5.2

Percentage of foundation cows and daughters of sires with records of 250 pounds of butterfat or better

	Percent
Foundation cows	94.7
Daughters of sire 1	60.0
Daughters of sire 2	56.2
Daughters of sire 3	61.1
Daughters of sire 4	57.9

Percentage of foundation cows and daughters of sires with records of less than 200 pounds of butterfat

	Percent
Foundation cows	0.0
Daughters of sire 1	.0
Daughters of sire 2	18.7
Daughters of sire 3	5.5
Daughters of sire 4	31.6

If environmental conditions were the same for the records of all of this group it is questionable which of these four sires possessed the better or the poorer inheritance. Sire 4 undoubtedly had the greater range. Some of his daughters gave over 350 pounds of butterfat, but there was very little difference between the percentage of his daughters and the percentage of the daughters of sires 2 and 3 with records over 250 pounds. He had by far the largest percentage of daughters with records under 200 pounds of butterfat, but he was bred to dams averaging 25 percent lower than the dams to which sire 1 was mated. It is apparent that where poor sires are used and there is no selection of the brood cows, the level of production will very rapidly sink to that governed by the inheritance possessed by the sires.

LIMITATIONS IN DETERMINATION OF HOW POOR A SIRE MAY BE

In the analysis of the survey of superior germ plasm, sires have been classed as poor when the average production of their daughters, in the herds in which the sires were used, was less than that of the dams by a considerable margin, and when less than half the daughters were

better than their dams. This was subject to certain modifications if the dams to which the sires were mated showed higher production than the herd average. As a matter of fact some of the sires classed as poor may be bringing about an improvement in the herd by eliminating some of the factors for low levels of production in their offspring that existed in the immediate ancestry. Whether or not this is the case depends on the hereditary make-up of the individual sire for the factors determining level of production. These poor sires may be divided into several groups for purposes of illustration.

(1) The sire that has a considerable concentration of factors determining low levels of production will lower the level of production of dams of any reasonably high level. Used on a herd of cows with a considerable concentration of factors for high levels of production, he would inject the inheritance for low levels into all his offspring. The offspring would not only be lower producers than their good dams, but they would also transmit to a part of their progeny in turn the inheritance for low production received from their sire.

(2) The sire that is heterozygous (mixed) in his inheritance for levels of production will transmit inheritance for high levels of production to some of his offspring and inheritance for low levels to others. Mated to poor cows, he may get some daughters that are considerably better than their dams and some that are no better or not so good. Mated to cows that were heterozygous in their inheritance for level of production, he may get some excellent offspring that approach homozygosity (purity) for high levels; some that are heterozygous in their inheritance for level of production and that are good or average producers; and some that are approaching homozygosity for the factors determining low levels of production. No consistent progress in improving the germ plasm will be made with such sires.

Level of production will vary greatly, of course, with the same inheritance under different environmental conditions. Cows on a ration consisting entirely of roughage, for instance, will produce from 70 to 75 percent as much as they would on a full grain ration in addition to roughage of the same quality. The number of milkings, the time the calf is carried, and other environmental conditions affect level of production.

(3) A sire carrying factors for intermediate levels of production might be mated to 600-pound dams, which may be considered a high level of production, and get daughters that would average only 500 pounds of butterfat. His inheritance might not enable him to transmit more than a 500-pound level, but it is also possible that it would not permit him to transmit less than a 350-pound level. In that case his 500-pound daughters might be more free of factors that would determine levels of production of less than 350 pounds of fat than were their 600-pound dams. Though such a sire would be rated as poor in a 600-pound herd, he might possibly improve the germ plasm of that herd by eliminating the downward variation to levels below 350 pounds.

The sires that increase production by a wide margin are sires that can be determined positively to possess an inheritance for higher levels of production than the dams with which they were mated. Unfortunately it is impossible to determine, except by a breeding test, how good some of the negative (poor) bulls may be. It may be said that this has been worked out with some of the sire indices by the simple

method of calculating the daughters' inheritance as being part way between that of the sire and the dam. If sires and dams that were homozygous for definite levels of production were available, such a method might be sufficiently accurate. It appears, however, that the great majority of our good animals possess an inheritance for quite a range in level of production. A 600-pound cow may—if heterozygous for level of production—transmit to some of her offspring hereditary factors for a production capacity of only 350 pounds of butterfat. Certain combinations of genetic factors might give results much higher or lower than the expected intermediate, particularly in crosses of unrelated lines that have been closely bred.

In table 24 is the record of the Holsetin-Friesian bull Friend Ona Hartog Korndyke when used in farmers' herds on the Huntley project and when used later in the Huntley Experiment Station herd. Both daughters and dams in the farmers' herds where he was first used were milked twice a day and fed a limited amount of grain along with good alfalfa hay. In the summer they were on irrigated pasture. The records as given are corrected for differences in age only. In the station herd he was mated to cows that when milked three times a day and fed a full grain ration had records that were 66 percent higher than those of the cows to which he was mated in the farmers' herds. The difference in the producing capacity of the two groups of cows to which he was mated was not actually as great as 66 percent, however, because the cows in the farmers' herds were not tested under conditions as favorable for maximum production.

TABLE 24.—*Transmitting record for milk and butterfat production of the Holstein-Friesian bull Friend Ona Hartog Korndyke in two herds when mated to dams of different levels of production*

Items	Farmer's herd	Experiment station herd
Daughter-dam pairs.....number	15	14
Average butterfat of daughters.....percent	3.73	3.52
Average butterfat of dams.....do	3.58	3.47
Increase of daughters.....do	+4.2	+1.4
Average milk production of daughters.....pounds	11,489	16,745
Average milk production of dams.....do	10,775	18,830
Increase (+) or decrease (−) of daughters.....percent	+6.9	−11.0
Average butterfat production of daughters.....pounds	429	589
Average butterfat production of dams.....do	386	653
Increase or decrease of daughters.....percent	+11.1	−10.0

This appears to be an illustration of a sire that possesses an inheritance for a level of production above that of the cows to which he was mated in the farmers' herds and below that of the cows to which he was mated in the experiment station herd. He is rated as poor in the station herd, but because of the evidence that he possesses an inheritance for a level of production above 350 pounds of butterfat under the feeding and environmental conditions existing in the farmers' herds, it is probable that he improved the germ plasm of the station herd by breeding out some of the downward variation even though he also lowered the upward variation.

In the Washington State College herd and the Western Washington Experiment Station herd the Holstein-Friesian sire Piebe Hero had the transmitting record shown in table 25.

TABLE 25.—*Transmitting record for milk and butterfat production of the Holstein-Friesian bull Piebe Hero used in 2 experiment station herds*

Item	Washington State College herd	Western Washington Experiment Station herd
Daughter-dam pairs.....number..	10	7
Average butterfat of daughters.....percent..	3.48	3.14
Average butterfat of dams.....do....	3.46	3.25
Increase (+) or decrease (−) of daughters.....do....	+0.6	−5.1
Daughters better than dams.....do....	70.0	28.6
Rating of sire for percentage of butterfat.....	F	P
Average milk production of daughters.....pounds..	15,305	12,506
Average milk production of dams.....do....	18,559	11,113
Increase (+) or decrease (−) of daughters.....percent	−17.5	+12.3
Daughters better than dams.....do....	10.0	57.1
Rating of sire for milk production.....	P	G
Average butterfat production of daughters.....pounds..	525	390
Average butterfat production of dams.....do....	634	357
Increase (+) or decrease (−) of daughters.....percent..	−17.2	+9.2
Daughters better than dams.....do....	10.0	71.3
Rating of sire for butterfat production.....	P	G

The records in the college herd were made on three and four milkings a day, and in the Western Washington Experiment Station herd the records were made on twice-a-day milking.

Why the butterfat percentage should have been slightly increased in one herd and decreased in the other is not clear. Perhaps the dams in the station herd possessed factors for low butterfat percentage and in these matings transmitted a level lower than the percentage expressed in their records. In that case, the sire too must have possessed an inheritance for quite a range in butterfat percentage. What was said of the bull Friend Ona Hartog Korndyke relative to inheritance for level of production may be applied to this bull also.

Further data showing the transmitting performance of sires when used on dams of different levels of production—partly due to differences in the environmental conditions under which the records were made—is shown in table 26.

TABLE 26.—*Comparison of transmitting ability of Holstein-Friesian sires when used in farm herds and experiment station herds with different environmental conditions* [1]

[All records calculated to a mature basis]

Sire	Records made under farm conditions (twice-a-day milking)				Records made under advanced register conditions (3-times-a-day milking; higher record dams)			
	Pairs	Milk	Butterfat		Pairs	Milk	Butterfat	
	Number	*Pounds*	*Pounds*	*Percent*	*Number*	*Pounds*	*Pounds*	*Percent*
Mapleside King Paul 181023 (H104):								
Daughters.....	8	11,453	407	3.55	38	17,727	624	3.52
Dams [2].....		10,130	359	3.54		17,065	577	3.38
Friend Ona Hartog Korndyke 277648 (A105):								
Daughters.....	15	11,489	429	3.73	25	16,691	589	3.53
Dams.....		10,775	386	3.58		18,381	637	3.46
Colonel Venus Piebe Paul 331222 [3] (H109):								
Daughters.....	13	10,319	378	3.66	14	14,918	540	3.63
Dams.....		7,025	266	3.78		14,058	507	3.61
King Paul Pontiac Rag Apple 331219 [3] (H111):								
Daughters.....	27	9,813	342	3.48	2	11,623	437	3.69
Dams.....		9,378	315	3.36		17,495	554	3.16

[1] Daughters and dams tested under similar conditions on farms and with the same opportunity in station herds.
[2] Dams in respective groups unrelated and of different levels of production.
[3] Sons of Mapleside King Paul.

TABLE 26.—*Comparison of transmitting ability of Holstein-Friesian sires when used in farm herds and experiment station herds with different environmental conditions*—Continued

[All records calculated to a mature basis]

Sire	Records made under farm conditions (twice-a-day milking)				Records made under advanced register conditions (3-times-a-day milking; higher record dams)			
	Pairs	Milk	Butterfat		Pairs	Milk	Butterfat	
	Number	*Pounds*	*Pounds*	*Percent*	*Number*	*Pounds*	*Pounds*	*Percent*
King Paul Canary Ormsby 356096 [3] (H114):								
Daughters	10	8,729	336	3.84	9	19,498	687	3.53
Dams		7,825	283	3.61		18,326	593	3.24
King Paul Helena Walker 348317 [3] (H112):								
Daughters	28	12,189	444	3.63	32	21,420	701	3.27
Dams		9,091	336	3.69		17,512	556	3.17
King Paul Lillian Walker 410809 [3] (H120):								
Daughters	11	11,610	405	3.48	19	16,231	573	3.53
Dams		8,437	304	3.59		17,792	633	3.56
Korndyke Walker Pontiac Prince 243835 (H257):								
Daughters	21	10,042	350	3.48	2	19,203	585	3.04
Dams		8,379	291	3.47		21,897	656	3.00
Pride of King Paul Uilkje 565312 (H169):								
Daughters [4]	4	10,347	376	3.63	3	18,025	657	3.64
Dams [4]		11,223	381	3.39		13,828	428	3.09

[3] Sons of Mapleside King Paul.
[4] Dams had better environmental and feeding conditions than daughters in farm herd.

All of these sires were used or bred in the Bureau of Dairy Industry herd at Huntley, Mont. They were loaned to farmers on the Huntley project, who mated them for the most part to grade cows. The daughters and their dams made their records on these farms, in most cases with little or no grain in their rations and on twice-a-day milking. On the strength of their showing in the farmers' herds these bulls were then used in the Bureau of Dairy Industry herds, or were loaned to State experiment stations. In the station herds they were mated to cows of higher levels of production, though the records were made under more favorable conditions, usually three milkings a day and on a full grain ration. On both the farms and in the stations, the daughters and dams have for the most part had comparable opportunities to show their producing ability. No attempt has been made to use factors to correct for the differences in environmental conditions that existed on the farms and in the station herds. Corrections were made for age only.

The record of the second sire, Friend Ona Hartog Korndyke, has been discussed.

With three of the sires the number of daughter-dam pairs tested under station conditions was too small to be significant. The results do help to show, however, how great the difference in the production level of the daughters may be when they are tested under very different environmental conditions and when they are out of dams of different levels of production. How much of the difference is due to environment and how much is due to the inheritance for higher level of production possessed by the dams in the station herds it is impossible to say.

Most types of bull indexes—the intermediate, the average production of daughters, or the Mount Hope—would have shown very different results for each of these sires when applied to the two sets of data. Because of the influence of the environmental conditions on the level of production and because of the influence of such factors as level of production and homozygosity or heterozygosity of the dams for factors determining level of production, it appears necessary to use all the data that bear on the problem if one is to gage accurately the inheritance for level of production possessed by a given sire. Even then, selection of the daughters tested and unequal opportunities of daughter and dam to express the maximum production that their inheritance makes possible may lead to an erroneous appraisal.

It should be emphasized that it is easy to underestimate the real value of a sire that is mated to dams of a very high level of production when his daughters do not come up to that level, unless he has also been tried on dams of a lower level of production.

The sire U. Neb. Klaver King 388329 is an interesting study because he was used to some extent in four different experiment station herds on dams that were uniformly high producers. Table 27 shows his breeding performance in these four herds.

TABLE 27.—*Transmitting record of the Holstein-Friesian sire U. Neb. Klaver King 388329 in 4 herds*

Item	Nebraska School of Agriculture	North Platte Experiment Station	University of Nebraska	Huntley Experiment Station
Milkings per day ... number	[1] 4	[1] 4	[1] 4	3
Daughter-dam pairs ... do	4	2	11	10
Butterfat of daughters ... percent	3.84	3.81	3.79	3.50
Butterfat of dams ... do	3.56	3.73	3.70	3.62
Increase (+) or decrease (−) of butterfat of daughters ... percent	+.28	+.08	+.09	−.12
Milk production of daughters ... pounds	18,157	17,752	17,313	18,921
Milk production of dams ... do	20,100	19,473	19,016	17,889
Increase or decrease of milk production of daughters ... pounds	−1,943	−1,721	−1,703	+1,032
Butterfat production of daughters ... do	697	678	656	663
Butterfat production of dams ... do	715	725	717	648
Increase or decrease of butterfat production of daughters ... pounds	−18	−47	−61	+15

[1] Corrected to 3.

The dams to which he was mated in the Huntley Station herd were not related to the dams in the three Nebraska herds, though some relationship does exist among the dams in the three Nebraska herds. The dams in the Huntley herd had an average milk yield of a little more than 2,000 pounds less than the average of the 17 dams in the Nebraska herds, and a somewhat lower percentage of fat.

There are two possible explanations of why this sire's daughters are higher producers of milk than were their dams in the Huntley Station herd and poorer producers than their dams in the three Nebraska herds. The dams in the Nebraska herds probably had a higher level of production than his inheritance measured up to. Difference in environmental conditions under which the animals were tested in the Nebraska herds and in the Huntley Station herd may have influenced the results to some extent, but it is probable that the

dams in the Nebraska herds were not homozygous for as high a level of production as was indicated by their records and that on the average they transmitted in these matings a lower level of production than the average of their actual yields. The dams in the Huntley Station herd may have been fairly homozygous for the level of milk yield indicated by their records.

The same reasoning can be applied to the results for percentage of fat, though in this case it would be the dams in the Nebraska herds that were more homozygous for the level of fat percentage expressed by their records whereas the Huntley dams must have transmitted lower levels for percentage of fat than were indicated by their records. The higher level of milk yield for the daughters in the Huntley Station herd may have had some depressing influence on the percentage of fat, though it does not seem probable that the differences in the level of milk yield between the daughters in the Huntley herd and those in the Nebraska herds is great enough to account for the marked differences in percentage of fat.

GREAT BREEDING DAMS

The forms used for the germ plasm survey were so designed as to permit following the line of female descent from left to right. They were of heavy cardboard to permit tacking on a wall. This enables the breeder to keep before him the entire picture of the breeding performance of his herd, so far as production is concerned, from the time he started keeping records. The records just being made of the daughters of a sire are entered on the correct space on the proper sire card when they are completed. By following along the same line on previous sire cards, the breeder has a comparison of the producing capacity of this newly tested daughter with that of her dam, granddam, great granddam, and so on; or he can compare her production with that of her paternal sisters by noting the production of the daughters of her sire that have already been entered on the same card. This system has been used for some time for the Department's field-station herds and has been found very helpful in following the progress of the herds.

Interest has been expressed in an analysis of the superior breeding dams that might be made from the superior germ plasm data. Some of the States are already stressing the importance of determining the superior breeding dams in breeders' herds.

There is every reason to believe that the inheritance governing level of production is received from both parents. If, however, one parent were pure in its inheritance for the factors that would determine a high level of production and the other parent were pure for the factors determining a low level of production, the parent with the high-level inheritance might appear to have more influence on the producing capacity of the daughter than the parent with the low-level inheritance. The germinal make-up of that daughter, however, would contain the inheritance received from both parents, and to a part of her progeny she would probably transmit the inheritance she received from the low-level parent. If the theory holds true—that fair, good, or excellent sires within a breed have the ability to transmit higher levels of production than are expressed by their dams—then with each succeeding cross of such sires the females of the herd would carry in their inheritance more factors that deter-

mine high levels of production. Therefore, although it is always desirable to know the good breeding dams, it would be more important to know them in a herd where only mediocre sires had been used than in a herd where a succession of good sires had been in service.

To select a young bull that has the greatest probability of possessing an inheritance with a considerable concentration of factors that determine high levels of production, it would be essential that both his sire and his dam have such a high concentration. It is possible, of course, on the law of chance, to secure such a bull from two parents that were heterozygous for levels of production, but in that case the son must have been fortunate enough to have received the best inheritance that was in each parent. Whether he did secure only the best that was in each parent will be known only by his record as a sire.

Superior breeding dams have left their marks on all of our breeds. Take a cross section of the Holstein-Friesian breed in the United States today and it will be found that the great majority trace to the cow DeKol 2d. In the Jersey breed in the United States most of the American-bred Jerseys will trace to the cow Coomassie, and in the Guernsey breed many of the animals will trace to May Rose II. These cows probably carried more factors for desirable characters than most of the animals of their day and therefore transmitted these superior qualities to their sons and daughters, who in turn were outstanding and were widely used.

Occasionally constitutional vigor or fertility enables a female to have a dominating influence on herds. In the Department of Agriculture herds, in which every female is raised, are examples of certain cows that because of the number of their own and their daughters' female progeny have become the predominating influence in the herd in the female line. Other female lines have been submerged as a result of failure to produce female offspring.

Greater emphasis has been put on the proved sire in recent years because the inheritance he possesses can be determined by the breeding test at a much earlier stage of his breeding life than is the case with the female, and also because his inheritance is passed along to perhaps all of the next generation of calves in a given herd, whereas the inheritance of a cow is passed on to only a few individuals. But when it comes to selecting an individual calf for its breeding value, it is just as important to know the germinal make-up of the dam as it is to know that of the sire, whether this be determined by her own breeding performance or by analysis of her pedigree based on the number of great breeding sires in her immediate ancestry.

An examination of production records through the female lines of descent with two or more successive crosses of proved sires will show how quickly the identity of the foundation cow with a high butterfat yield is lost in her descendants under the leveling influence of the inheritance introduced through two or three sires. A foundation cow's record may rank toward the top, but the relative rank of her granddaughter in her generation may be entirely changed. The germ plasm of cows that are perhaps approaching homozygosity for very high levels of production may be very rapidly diluted and changed in later generations by successive matings to poor sires. This has been shown in the preceding discussions.

THE SELECTION OF SIRES WITH THE KIND OF GERM PLASM THAT WILL IMPROVE PRODUCING ABILITY

To advise all those who are seeking sires that will improve the producing capacity of their herds to seek proved sires that have demonstrated their ability by the progeny test is rather futile, because there are so few meritorious proved sires available. It is undoubtedly true, as has often been stated, that if the amount of record keeping was increased, a great many more valuable transmitting sires would be found. But even if the number of cows tested was increased from less than 2 percent, as at present, to more than 50 percent, it is not probable that enough meritorious sires would be found to head a very large percentage of our herds. Then too, young bulls must be tested by being used if the supply of meritorious sires is to be kept up in the future.

It has been the theory of the authors that if nothing but sires whose merit had been definitely proved were used in a given herd, that herd would finally carry many of the factors for determining high levels of production. Each succeeding cross of these sires of proved merit would help to eliminate the factors that make low levels of production possible. The purification of the germ plasm would proceed in very much the same manner as grading up from scrub cattle with registered bulls of any given breed. The first-cross animals are likely to have some resemblance to the breed represented by the sires used. This resemblance increases with each succeeding cross until after several crosses of such registered sires the resulting females cannot be distinguished in appearance from the registered cows of the breed.

The first question to be raised regarding the probability of success is whether or not meritorious sires that are unrelated or distantly related have the same genetic make-up. If the genetic make-up is different for each sire, then there is the possibility that mating the daughters of one sire to another sire will not result in increased homozygosity, although production might be increased.

How long it would take to reach homozygosity by the continued use of sires of proved merit would depend on the degree of homozygosity of the foundation cows and the amount of error in gaging the inheritance of the sires used. This is a long-time method when one is working with something as complicated in inheritance as milk and butterfat production. The many limitations in livestock reproduction and in the attempt to bring about improvement through one sex only add to the time involved.

While this question cannot be answered finally at this time, it does appear from experimental work and other evidence that meritorious sires within a breed have the same genetic make-up, and that if they are adequately and definitely proved, mating such sires to each other's daughters, even though the sires are unrelated, will be followed by good results. There is very often a question as to whether the proving has been sufficiently equitable and free from selection to permit an accurate appraisal of a sire's inheritance. It is often very difficult, too, to determine the relative level of production for which a sire may approach homozygosity.

Granting that the meritorious sires within a breed do possess the same genetic make-up for a given level of production, then the solution of the source of bulls for improvement of the mass of dairy cattle

appears to lie in finding a sufficient number of breeders who are willing to go to the trouble and expense of discovering the sires of definitely proved merit and using them over a period of years. These herds would then become the source of seed stock that could be depended on to furnish young bulls that would improve the germ plasm of our herds for higher levels of production.

The selection of the young bulls that could be depended upon with some certainty for the right kind of superior germ plasm would be based on the fact that they were sons of sires of definitely proved merit and that their dams, maternal granddams, maternal great-granddams, and so on were daughters of such meritorious sires.

Evidence that sons of meritorious sires have a better-than-average chance of possessing superior germ plasm is in the data secured by the Bureau of Dairy Industry through taking sons of the proved sires used in the experimental breeding herds and placing them in farmers' herds to determine their transmitting ability for production.

Table 28 shows the transmitting ability of bull calves, sons of proved sires, that have been proved in farmers' herds in the vicinity of the Huntley, Mont., station.

TABLE 28.—*The average production of the daughter-dam pairs of 49 sires*

[These sires were bred by the U. S. Bureau of Dairy Industry and used in farmers' herds in the vicinity of the Huntley Experiment Station, Huntley, Mont.; all records calculated to mature basis]

Sire no.	Daughter and dam comparisons	Production of daughters			Production of dams			Increase (+) or decrease (−) in production of daughters over dams		
		Milk	Butterfat		Milk	Butterfat		Milk	Butterfat	
	Number	*Pounds*	*Percent*	*Pounds*	*Pounds*	*Percent*	*Pounds*	*Pounds*	*Percent*	*Pounds*
15 SIRES, SONS OF MAPLESIDE KING PAUL										
H107	23	11,380	3.82	434	9,358	3.73	349	+2,022	+0.09	+85
H109	13	10,319	3.66	378	7,025	3.78	266	+3,294	−.12	+112
H111	27	9,813	3.48	342	9,378	3.36	315	+435	+.12	+27
H112	28	12,189	3.63	444	9,091	3.69	336	+3,098	−.06	+108
H113	6	9,618	3.51	338	9,669	3.26	315	−51	+.25	+23
H114	10	8,729	3.84	336	7,825	3.61	283	+904	+.23	+53
H115	18	11,509	3.52	406	9,320	3.53	330	+2,189	−.01	+76
H116	10	12,203	3.56	435	9,798	3.66	358	+2,405	−.10	+77
H117	30	10,330	3.68	380	10,749	3.58	385	−419	+.10	−5
H118	21	11,597	3.59	418	10,290	3.57	367	+1,307	+.02	+51
H120	11	11,610	3.48	405	8,437	3.59	304	+3,173	−.11	+101
H121	7	13,034	3.57	466	11,937	3.62	433	+1,097	−.05	+33
H123	14	9,742	3.47	339	7,458	3.44	257	+2,284	+.03	+82
H126	33	13,625	3.61	490	11,712	3.58	419	+1,913	+.03	+71
H127	9	9,624	3.53	340	7,400	3.70	274	+2,224	−.17	+66
Total	260	2,921,334		105,479	2,488,751		89,161			
Average		11,236	3.61	406	9,572	3.58	343	+1,664	+.03	+63
18 SIRES, SONS OF FRIEND ONA HARTOG KORNDYKE										
H130	8	10,081	3.58	354	8,214	3.76	309	+1,867	−0.18	+45
H131	8	9,439	3.91	369	7,909	3.67	291	+1,530	+.24	+78
H132	14	11,654	3.68	428	9,920	3.65	362	+1,734	+.03	+66
H135	13	11,064	3.55	393	9,853	3.51	346	+1,211	+.04	+47
H136	3	9,678	3.68	357	8,415	3.84	324	+1,263	−.16	+33
H137	3	11,084	3.84	426	8,245	4.51	373	+2,839	+.67	+53
H139	9	11,168	3.33	372	11,269	3.44	388	−101	−.11	−16
H141	17	11,759	3.56	418	10,711	3.54	379	+1,048	+.02	+39
H145	7	11,434	3.91	447	9,490	3.61	344	+1,944	+.31	+103
H147	7	9,134	3.64	332	8,756	3.47	298	+378	+.17	+34
H148	4	13,165	3.45	455	10,150	3.28	334	+3,015	+.17	+121
H151	17	10,906	3.48	380	9,583	3.46	332	+1,323	+.02	+48
H152	3	10,664	4.05	432	8,001	4.15	332	+2,663	−.10	+100
H154	11	14,437	3.55	512	10,893	3.48	379	+3,544	+.07	+133

TABLE 28.—*The average production of the daughter-dam pairs of 49 sires*—Contd.

[These sires were bred by the U. S. Bureau of Dairy Industry and used in farmers' herds in the vicinity of the Huntley Experiment Station, Huntley, Mont.; all records calculated to mature basis]

Sire no.	Daughter and dam comparisons	Production of daughters			Production of dams			Increase (+) or decrease (−) in production of daughters over dams		
		Milk	Butterfat		Milk	Butterfat		Milk	Butterfat	
	Number	*Pounds*	*Percent*	*Pounds*	*Pounds*	*Percent*	*Pounds*	*Pounds*	*Percent*	*Pounds*
18 SIRES, SONS OF FRIEND ONA HARTOG KORNDYKE—Continued										
H157	4	13, 235	3. 47	459	12, 233	3. 33	408	+1, 002	+. 14	+51
H158	5	15, 512	3. 27	508	10, 107	3. 37	341	+5, 405	−. 10	+167
H161	15	12, 581	3. 32	417	11, 373	3. 11	354	+1, 208	+. 21	+63
H167	12	11, 393	3. 70	421	11, 292	3. 68	412	+101	+. 02	+9
Total	160	1, 854, 617		66, 032	1, 610, 066		56, 622			
Average		11, 591	3. 56	413	10, 063	3. 52	354	+1, 528	+. 04	+59
7 SIRES, SONS OF COLANTHA PONTIAC HERO										
A107	17	9, 959	3. 69	367	8, 628	3. 68	318	+1, 331	+0. 01	+49
A108	8	9, 003	3. 46	307	9, 068	3. 28	298	−65	+. 18	+9
A109	11	10, 229	3. 45	354	9, 230	3. 44	318	+999	+. 01	+36
A119	6	10, 457	3. 72	390	7, 611	3. 45	263	+2, 846	+. 27	+127
A120	8	10, 030	3. 59	361	8, 596	3. 42	294	+1, 434	+. 17	+67
A121	14	10, 452	3. 56	373	9, 915	3. 55	352	+537	+. 01	+21
A126	4	12, 082	3. 63	438	10, 999	3. 52	387	+1, 083	+. 11	+51
Total	68	691, 484		24, 791	617, 990		21, 694			
Average		10, 169	3. 59	365	9, 088	3. 51	319	+1, 081	+. 08	+46
3 SIRES, SONS OF PRIDE OF THE BESS BURKES										
H169	3	18, 025	3. 52	657	13, 828	3. 09	428	+4, 197	+0. 43	+229
H170	8	9, 790	3. 89	382	10, 579	3. 69	390	−789	+ 20	−8
H175	6	16, 893	3. 93	664	16, 830	3. 72	625	+63	+. 21	+39
Total	17	233, 753		9, 011	227, 096		8, 154			
Average		13, 750	3. 86	530	13, 359	3. 59	480	+391	+. 27	+50
6 SIRES, SONS OF MISCELLANEOUS SIRES										
H104 [1]	8	11, 453	3. 55	407	10, 130	3. 54	359	+1, 323	+0. 01	+48
H105	13	10, 266	3. 67	377	10, 030	3. 64	365	+236	+. 03	+12
H129	13	11, 434	3. 56	409	10, 110	3. 52	356	+1, 324	+. 04	+53
H257	21	10, 042	3. 48	350	8, 379	3. 47	291	+1, 663	+. 01	+59
A104	4	10, 611	3. 59	380	8, 846	3. 85	341	+1, 765	−. 26	+39
A105 [2]	15	11, 489	3. 73	429	10, 775	3. 58	386	+714	+. 15	+43
Total	74	799, 385		28, 779	715, 828		25, 510			
Average		10, 803	3. 60	389	9, 673	3. 57	345	+1, 130	+. 03	+44
Grand total	579	6, 500, 573		234, 092	5, 659, 731		201, 141			
Average		11, 227	3. 60	404	9, 775	3. 55	347	+1, 452	+. 05	+57

[1] Mapleside King Paul (see above).
[2] Friend Ona Hartog Korndyke (see above).

The same information has been developed for sons of proved sires—Holstein-Friesians and Jersey—used in the station herd at Beltsville when these sons were proved in farmers' herds in that vicinity.

In table 28 it will be noted that under the conditions prevailing on the farms on which these sires were used, the 49 sires had 579 daughters

that produced an average of 1,452 pounds more milk and 57 pounds more butterfat than did their dams. Only 3 of the 49 sires failed to increase the average yield of butterfat.

In the Beltsville data referred to, the average increase in milk yield for 370 daughters of 25 Holstein-Friesian sires was 1, 201 pounds, and the average increase in butterfat yield for 253 daughters of 23 sires was 48 pounds. Only 3 of the 23 sires failed to bring about an increase in the average butterfat yield of their daughters. The yields of the 224 daughters of 27 Jersey sires showed an average increase of 46 pounds of butterfat over their dams. Four of the twenty-seven sires had daughters whose average butterfat yield was below that of their dams.

This evidence indicates that these sons of sires of proved merit had the ability, in the great majority of cases, to increase the level of production in the herds in which they were used. How much higher this level of production might prove to be under more favorable environmental conditions it is not possible to say.

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Appendix

Breeders, State Universities, Colleges, and Experiment Stations Cooperating in the Survey of Superior Germ Plasm in Dairy Cattle

Following is a list of the breeders of dairy cattle, the State universities, colleges, and experiment stations, and the Federal experiment stations that have cooperated in providing data on their herds for this survey of superior germ plasm in dairy cattle. The breeders are given alphabetically and by States. With each name is given the breed represented and information as to whether the animals are registered, grades, or both.[1]

Appreciation is here expressed to J. B. Parker, W. E. Wintermeyer, A. B. Nystrom, and R. C. Jones, Extension Specialists of the Bureau of Dairy Industry, and to the men named below, appointed by their respective agricultural experiment stations and extension services, who supervised the making of the survey in their respective States, and to their assistants, for their part in this work. Their cooperation and initiative makes possible this report.

Alabama, F. W. Burns; Arizona, C. F. Rowe; Colorado, G. A. Smith; Connecticut, A. I. Mann; Delaware, T. A. Baker; Georgia, Zeno A. Massey and F. W. Fitch; Idaho, D. Fourt; Illinois, C. S. Rhode; Indiana, E. T. Wallace; Iowa, Floyd Johnson; Kansas, J. W. Linn; Kentucky, George M. Harris; Louisiana, R. H. Lush; Massachusetts, C. J. Fawcett; Michigan, J. G. Hays; Minnesota, H. R. Searles; Mississippi, L. A. Higgins; Missouri, M. J. Regan; Montana, J. O. Tretsven; Nebraska, E. C. Scheidenhelm; New Hampshire, E. F. Eastman; New Jersey, E. J. Perry; New York, L. W. Lamb; North Carolina, C. D. Grinnells; North Dakota, E. J. Haslerud; Ohio, Ivan McKellip; Oklahoma, A. H. Kuhlman; Oregon, R. W. Morse; Pennsylvania, C. R. Gearhart; South Carolina, E. C. Elting and C. G. Cushman; South Dakota, R. A. Cave; Tennessee, C. A. Hutton; Texas, C. N. Shepardson; Utah, George Q. Bateman; Vermont, E. H. Loveland; Virginia, C. G. Connelly; Washington, O. J. Hill; Wisconsin, Gordon Dickerson; Wyoming, H. S. Willard.

Commercial Herds

ALABAMA

Kilby Dairy Farm, Montgomery	Guernsey, registered.

ARIZONA

Chesney Farm, Glendale	Jersey, registered.
Coman Holstein Farm, Route 5, Phoenix	Holstein, registered.
Ewing, J. W., Route 1, Box 134, Tucson	Guernsey, grade.
Fairview Dairy, Route 1, Box 354, Tucson	Holstein, registered and grade. Guernsey, registered and grade.
Fletcher, Mrs. Marie, Route 5, Phoenix	Jersey, registered.
Mission Ranch, Route 8, Phoenix	Holstein, registered and grade. Guernsey, registered and grade.
Painter, James, Route 1, Tempe	Holstein, registered.
Phoenix Indian School, Phoenix	Holstein, registered and grade.

COLORADO

Colorado School for Deaf and Blind, Colorado Springs.	Holstein, registered.
Colorado State Home for Dependent Children, Denver.	Do.
Henry, C. W., Greeley	Do.
Holland Farm Dairy Co., Colorado Springs	Holstein, registered and grade.
Kirk, Chas. E., Monument	Guernsey, registered.
Loving, J. W., Pueblo	Guernsey, registered and grade.
Modern Woodmen of America Sanitarium, Colorado Springs.	Holstein, registered.
Myron Stratton Home, Colorado Springs	Do.

[1] Records of several herds were received from Maryland too late for analysis or inclusion among cooperators.

Roemer, Robt. and Catherine, Fort Collins	Guernsey, registered.
Sinton, George T., Colorado Springs	Holstein, registered.
Temple, Earl, Fort Collins	Jersey, registered.
Tienken, John, Colorado Springs	Do.
Turner, George S., Canon City	Holstein, registered.

CONNECTICUT

Alsop, J. W., Avon	Ayrshire, registered.
Brock, C. W., Northford	Do.
Calhoun, Frank E., Cornwall	Guernsey, registered.
Child, William C., Woodstock	Guernsey, registered and grade.
Connecticut Reformatory, Cheshire	Holstein, registered.
Gold, T. S., West Cornwall	Do.
Grant, A. H., Melrose	Ayrshire, registered.
Grant, Mrs. K. R., Melrose	Shorthorn, registered.
Hescock, Robt. E., North Stonington	Guernsey, grade (2 or 3 registered).
Holcomb, Tudor J., West Granby	Guernsey, registered and grade.
Kelsey, C. W. (estate), Middletown	Holstein, registered.
Long Lane Farm, Middletown	Holstein, registered and grade.
Mitchell, R. C. & Son, Southbury	Do.
Newton, C. R., Woodbridge	Holstein, registered.
Riddle, Mrs. J. W., Farmington	Guernsey, registered.
Sanford, L. R., Litchfield	Guernsey, registered and grade.
Selden Bros., Haddon Neck	Guernsey, registered.
Strickland, Harold, Rockfall	Do.
Thomsen, D. L., Brookfield Center	Do.
Webster, A. Benj., Litchfield	Guernsey, registered (2 or 3 old cows were grades).
Willard, Daniel, Salisbury	Holstein, registered.

DELAWARE

Haskell, H. G., Wilmington	Guernsey, registered.
Winterthur Farms (H. F. Dupont) Wilmington	Holsteins, registered.

GEORGIA

Allen's Invalid Home, Milledgeville	Jersey, registered.
Georgia Baptist Orphans' Home, Hapeville	Holstein, registered.
Hardman, J. B., Commerce	Jersey, registered.
Hooks, J. H., Warthen	Jersey, registered and grade.
Pebble Hill Products Co., Thomasville	Jersey, registered.
Wooldridge, J. C., Columbus	Do.

IDAHO

Davis, R. T., Weiser	Holstein, registered.
Pritzl, Chas. J., New Plymouth	Guernsey, registered.
Shutwell, Roy, Boise	Holstein, registered.
Steele, H. F. & Son, Gooding	Guernsey, registered.
Tenckinck, L. J., Twin Falls	Holstein, registered.

ILLINOIS

Beard, L. Russell, Hebron	Holstein, registered.
Bogardus, C. S., Clinton	Guernsey, registered and grade.
Bridge, Clay B., Orangeville	Holstein, registered.
Davis, F. M., Rockford	Jersey, registered and grade.
Eppel, H. T. & Son, Woodstock	Holstein, registered.
Folgate, Ray, Dakota	Brown Swiss, registered.
Gahlbeck & Lange, Woodstock	Holstein, registered.
Gardner, W. H., Solon Mills	Do.
Maywood Farms, Hebron	Do.
Phillips, H. M., Lena	Holstein, registered and grade.
Rock River Farm, Byron	Holstein, registered.
Raleigh, W. T., Freeport	Do.

Rockyford Dairy, Amboy	Holstein, registered.
Sinissippi Farm, Oregon	Do.
Swanzey, J. H., Ridott	Do.
Turner & Winn, Richmond	Do.
Von Loh, Geo. & Sons, Baileyville	Holstein, registered and grade.
Wood, Harry M., Delavan	Holstein, registered.
Yordy, Chris, Morton	Guernsey, registered and grade.
Zurbriggen, Herman, Scioto Mills	Holstein, registered.

INDIANA

Arbogast, G. C., Selma	Holstein, registered.
Butler, S. S., Pleasant Lake	Jersey, registered.
Carter, H. A., Connersville	Guernsey, registered.
Chauncey Rose School, Terre Haute	Holstein, registered.
Dietrich & Thornton, Bremen	Guernsey, registered.
Eby, Mervin, Elkhart	Do.
Hershberger, C. C., Bremen	Do.
Hunter, E. E. & Son, Angola	Jersey, registered.
Jackson, Therl, Yorktown	Holstein, registered.
Kelsey, Lesh & Son, Huntington	Guersey, registered.
Mazelin, D. F., Berne	Holstein, registered.
Meeker, Ray & Son, Muncie	Do.
Morgan, Glen, Westville	Do.
Mosser, Sol, Geneva	Jersey, registered.
Myers, W. H., Arcadia	Guernsey, registered.
Newman, John, Culver	Holstein, registered.
Rauth Bros., Boonville	Guernsey (mostly registered).
Reichard, O. E., Kewanna	Jersey, registered.
Schwartz, D. D., Berne	Holstein, registered.
Schwartz, Jacob J., Berne	Do.
Schwartz, P. D., Berne	Do.
Sisters of Providence, St. Mary-of-the-Woods	Holstein, registered.
Stanley, Orlo, Richmond	Do.
Steed, Oliver K., Portland	Jersey, registered.
Steele, H. P., Butler	Do.
White, P. L., Oxford	Do.

IOWA

Birker, Matt, Vinton	Holstein, registered.
Chester, F. A. & Sons, Plainfield	Do.
Clampitt, R. R., New Providence	Milking Shorthorn, registered.
Cline, Kirk, Vinton	Jersey, registered and grade.
Dengler, Walter, Davenport	Guernsey, registered and grade.
Dupont, P. I., Spechts Ferry	Holstein, registered and grade.
Eckles, Wm., Eldora	Do.
Eiten, Fred, Wellsburg	Do.
Emmert, C. T., Whitten	Holstein, registered.
Epperson, C. C., Vinton	Jersey, registered and grade.
Finster, Roy N., Eldora	Holstein, registered.
Fuehrer, Ed., Shellsburg	Jersey, registered.
Gillette, Wm. R. & Sons, Fostoria	Holstein, registered.
Haight, C. W., Winfield	Do.
Hamer, O. L., Waterloo	Do.
Hansen & Merner, Cedar Falls	Do.
Hastings, I. C., Garner	Do.
Heald, J. M., Nashua	Do.
Hempler, A. J., Garnavillo	Guernsey, registered and grade.
Hollingsworth, A. B., Mount Pleasant	Do.
Hoppe Bros., Gladbrook	Holstein, registered and grade.
Iowana Farms, Davenport	Holstein, registered.
Jannings, Glenn, Donnellson	Jersey, registered.
Johnson, Harry, Newell	Holstein, registered and grade.
Kinsley, R. G., McGregor	Jersey, registered.
Klotz, W. H., Fredericksburg	Holstein, registered.
Krekel, A. G. & Son, Burlington	Jersey, registered and grade.

Ladwig, G. A., Fredericksburg	Milking Shorthorn, registered.
Learn, R. F., Clermont	Jersey, registered.
Lenth, L. C., Elkader	Holstein, registered.
Lynes, J. J. & Sons, Plainfield	Ayrshire, registered and grade.
Mark, C. A. & Son, Iowa Falls	Holstein, registered.
Martin, J. N., New Providence	Jersey, registered.
Meyer, Irwin F., McGregor	Milking Shorthorn, registered.
Miller, L. H., Waterloo	Holstein, registered and grade.
Miller, M. W., Wellman	Guernsey, registered.
Miller, J. Wilbert, Waterloo	Holstein, registered and grade.
Mitchell, E. M. & Sons, Reinbeck	Milking Shorthorn, registered.
Mitchell, W. D., Reinbeck	Holstein, registered.
Myers & Hickey, Adel	Brown Swiss, registered.
Mueller, Geo. & Son, Lone Tree	Holstein, registered.
Olmstead, D. N., McGregor	Jersey, registered and grade.
Pancratz, A. M., Jr., Dubuque	Guernsey, registered and grade.
Putnam, Mrs. B. W., Eldora	Jersey, registered.
Rehder Bros., Gladbrook	Holstein, registered.
Reiss, Ezra C., Garrison	Holstein, registered and grade.
Reiss, J. F., Garrison	Holstein, registered.
Sanders, Claude, Eldora, Route 1	Holstein, registered and grade.
Scott, Leo, Mount Pleasant	Jersey, registered.
Shaulis & Swift, Waterloo	Holstein, registered.
Sherman, J. F., Edgewood	Guernsey, registered and grade.
Sherman, H. A., Iowa Falls	Brown Swiss, registered.
Smith, Roy J., Spirit Lake	Jersey, registered and grade.
Soldiers and Orphans Home, Davenport	Holstein, registered.
State Training School, Eldora	Do.
Stence, Mart, Elkader	Do.
Thompson, R. C., Vinton	Do.
Tieden, George & Son, Elkader	Holstein, registered and grade.
Tracy, E. E., Nashua	Red Polled, registered.
Tyler & McGovern, Central City	Holstein, registered and grade.
Van Nice, G. C., Vinton	Holstein, registered.
Von Glon, G. J., Breda	Do.
Wehrman, Harold, Luzerne	Do.
Warren, J. W. & Son, Iowa City	Holstein, registered and grade.
Wehling, Henry J., Anamosa	Holstein, registered.
Wood, R. C., Traer	Do.

KANSAS

Ainsworth, W. C., Elmo	Ayrshire, registered.
Allen County Farm, Carlyle	Holstein, registered and grade.
Barlow-Keas, Effingham	Ayrshire, registered.
Chacey, C. L., Leavenworth	Jersey, registered and grade.
Collins, Swell-Bechtelheimer, Sabetha	Holstein, registered.
Dunkin, James, Columbus	Jersey, registered and grade.
Duwe, Henry, Freeport	Brown Swiss, registered.
Dusenbury & Son, Anthony	Ayrshire, registered.
Evans, R. L., Hutchinson	Holstein, registered.
Ennefer, R. C., Prescott	Do.
Farley, Bruce, Athol	Do.
Faulconer Bros., Eldorado	Holstein, grade.
Feess, Otto, Parsons	Guernsey, registered and grade.
Grauerholz, W. H., & Son, Kensington	Jersey, registered.
Hatesohl, Henry, Greenleaf	Holstein, registered.
Hoffman, Frank, Pretty Prairie	Do.
Hoffman, H. H., Route 5, Abilene	Ayrshire, registered.
Hostetler, H. E., Harper	Holstein, registered.
Jamison, J. A., Leavenworth	Do.
Johnson, Paul R., Independence	Guernsey, registered.
McCormick, Carl, Cedar	Holstein, registered.
Meierkord, H. J., Linn	Do.
Miller, J. Fred, Larned	Jersey, registered and grade.
Osawatomie State Hospital, Osawatomie	Holstein, registered.
Porter, T. C., Overland Park	Holstein, registered and grade.

Reece, L. H., Earleton	Jersey, registered.
Regier, E. B., White Water	Holstein, registered.
Robinson, W. S., Nashville	Ayrshire, registered.
St. Josephs Orphans Home, Abilene	Holstein, registered and grade.
Shultz, M. A., Pretty Prairie	Do.
Smith, G. W., & Son, Highland	Jersey, registered.
Strahm, L. B., Sabetha	Holstein, registered.
State Hospital for Epileptics, Parsons	Do.
Strickler, Fred, Hutchinson	Ayrshire, registered.
The Sun Farm, Inc., Parsons	Guernsey, registered and grade.
Windmoor Farm, Edna	Jersey, registered.
Wempe, F. B., Frankfort	Do.
Wheelock, D. L., Clay Center	Do.
Wonsetler, L., & Sons, Larned	Jersey, registered and grade.

KENTUCKY

Berea College, Berea	Holstein, registered.
Harrison, M. D., Farmington	Jersey, registered.
Walnut Hall Farm, Donerail	Guernsey, registered and grade.
Weikel, Fred, St. Matthews	Holstein, registered.

LOUISIANA

Idlewild Dairy Farm, Patterson	Jersey, registered and grade.

MASSACHUSETTS

Ames, John S. (Langwater Farm), Easton	Guernsey, registered.
Barnard, D. & Son, Shelburne Falls	Milking Shorthorn, registered.
Bridgewater State Farm, Bridgewater	Holstein, registered and grade.
Cande, Donald (Flintstown Farm), Dalton	Milking Shorthorn, registered.
Carpenter, J. T., Shelburne Falls	Jersey, registered.
Castle Hill Farm, Whitinsville	Ayrshire, registered.
Chapin, A. M., Sheffield	Holstein, registered.
Cook, Joseph & Gordon, Amherst	Do.
Crocker, C. T., Princeton	Milking Shorthorn, registered.
Davenport, Charles, Leyden	Guernsey, registered.
Davenport, W. J., Shelburne	Holstein, registered.
Dewey, T. J., Westfield	Jersey, registered.
Ellis, John G., (Highfield Farm) Lee	Holstein, registered.
Elm Hill Farm, Brookfield	Jersey, registered.
Elm Tree Farm, Rehoboth	Holstein, registered.
Elmwood Farm, Uxbridge	Brown Swiss, registered.
Fernald, Walter E. (State School) Waverly	Holstein, grade.
Foxboro State Hospital, Foxboro	Do.
Galusha, Arthur, Williamstown	Guernsey, registered.
Galusha, D. J., Williamstown	Do.
Gardner State Colony, Gardner	Holstein, grade.
Grafton State Hospital, Grafton	Do.
Graves, Edw., Conway	Jersey, registered.
Hurlburt, Walter, Ashley Falls	Holstein, registered.
Kelly, Shaun, Richmond	Do.
Kimball, Ivory, Rehoboth	Ayrshire, registered.
Lakeville State Sanitarium, Lakeville	Holstein, grade.
Loud, C. G., Northampton	Holstein, registered.
Massachusetts State Infirmary, Tewksbury	Holstein, grade.
Massachusetts State Prison, Norfolk	Do.
Medfield State Hospital, Medfield	Do.
Merrill, S. M., Ipswich	Guernsey, registered.
Monson State Hospital, Monson	Holstein, grade.
Mount Hermon School, Mount Hermon	Holstein, registered.
Mount Hope Farm (E. P. Prentice), Williamstown.	Guernsey and mixed.
Mudgett, Vernon (Deershorn Farm) Sterling	Guernsey, registered.
Norfolk County Agricultural School, Walpole	Guernsey, registered.
Northampton State Hospital, Northampton	Holstein, grade.
Rutland State Sanitarium, Rutland	Do.

Sabine, Stephen (Westfield Farm) Groton	Guernsey, registered.
Sibley, John R., Spencer	Jersey, registered.
Standish, H. Arthur, Middleboro	Ayrshire, registered.
Streeter, A. H., Cunnington	Milking Shorthorn, registered.
Sweet, J. S., West Mansfield	Jersey, registered.
Taunton State Hospital, Taunton	Holstein, grade.
Timmons, George, Ware	Guernsey, registered.
Tufts, D. L. (Unkamet Farm) Coltsville, Pittsfield.	Do.
Wells, F. V., (Quonquont Farm) Whatley	Holstein, registered.
West, E. P. & Son, Hadley	Do.
West, Wm. R. (Est.) North Dartmouth	Guernsey, registered.
Westboro State Hospital, Westboro	Holstein, grade.
Wilde, H. George, (Highlawn Farm) Lenox	Jersey, registered.
Worcester State Hospital, Worcester	Holstein, Grade.
Wigglesworth, Ed. W., Topsfield	Guernsey, registered.
Wrentham State School, Wrentham	Holstein, grade.

MICHIGAN

Arnold, C. W. & Son, Perry	Jersey, registered.
Bourassa, Henry, Linwood	Holstein, registered.
Campbell, L. E., Charlotte	Holstein, registered and grade.
Carman Farms, Fennville	Jersey, registered.
Chorpening & Owens, Marshall	Guernsey, registered.
Fisher, Walter, Crystal Falls	Holstein, registered.
Freshour & Son, Mason	Do.
Gleason, Harry & Son, Three Rivers	Do.
Hunt, L. C., Eaton Rapids	Do
Ionia State Hospital, Ionia	Do.
Johnson, Henry W., Fennville	Jersey, registered.
Jones, Arthur L., Three Rivers	Holstein, registered.
Kalamazoo State Hospital, Kalamazoo	Do.
Knott, Adolph, Niles	Guernsey, registered
Knott, Fred, Niles	Do.
Lakefield Farms, Clarkston	Holstein, registered.
Lapeer Home and Training School, Lapeer	Do.
Larro Research Farm, Redford	Holstein, registered and grade.
Marquette Prison, Marquette	Holstein, registered.
Michigan Reformatory, Ionia	Do.
Michigan State Sanatorium, Howell	Do.
Miller, D. G. & Sons, Farm, Eaton Rapids	Do.
Newberry State Hospital, Newberry	Do.
Nitz, Adolph, Pigeon	Brown Swiss, registered and grade.
Olmstead, Howard, Bronson	Holstein, registered and grade.
Parsons, E. M. & Sons, Linwood	Holstein, registered.
Perrine, A. H., Rives Junction	Do.
Pontiac State Hospital, Pontiac	Do.
Ruehs, E. W., Caledonia	Guernsey, registered.
Ruehs, F. W. & Son, Caledonia	Do.
Sprague, W. W., Battle Creek	Holstein, registered.
Straub, Doan, Galien	Do.
Ternes, A. P. (Ternes Farms), Tecumseh	Brown Swiss, registered.
Vincent, Alfred, Durand	Jersey, registered.
Wardin, Albert P., Hemlock	Holstein, registered and grade.
Wayne County Training School, Northville	Holstein, registered.
Woodard, R. C. & Sons, Elsie	Do.
Woodworth, H. & Sons, Potterville	Do.

MINNESOTA

Astroth, Frank, St. Paul	Jersey, registered.
Brackett, C. R., Long Lake	Do.
Gluek Brewing Co., Minneapolis	Guernsey, registered.
Highcroft Farm, Wayzata	Do.
Nahrgang, John H., Lewiston	Do.
Pond, H. H., Shakopee	Holstein, registered.
Stevernagel, Otto & Son, Lewiston	Do.

Thompkins, D. D., Byron	Guernsey, registered.
Tuttle, Mr. and Mrs. Geo. T., Crystal Bay	Jersey, registered.
Wirt, E. J., Lewiston	Guernsey, registered.
Woodend Farm, Mound	Do.

MISSISSIPPI

Buntin, J. T. (Gayoso Farm), Horn Lake	Guernsey, registered.

MISSOURI

Adams, E. C., Blue Springs	Holstein, registered and grade.
Booth, H. R., Hamilton	Guernsey, registered.
Brown, Robert E., Ethlyn	Holstein, registered.
Carpenter, W. G., Greenwood	Do.
Chapman Dairy, Lees Summit	Holstein, registered and grade.
Cooper, B. Frank, Hannibal	Jersey, registered and grade.
Deters, H. T. & Son, Bowling Green	Holstein, registered.
Dooley, Garland, Eldon	Jersey, registered.
Finck, E. P., St. Charles	Holstein, registered and grade.
Finck, E. P., St. Charles	Jersey, registered and grade.
Gentemann, F. A., O'Fallon	Guernsey, registered.
Harlan, O. O., Marionville	Jersey, registered.
Head, S. R., Hannibal	Do.
Luke, A. W., Clarksville	Do.
McDaniel, C. B. & Sons, Carthage	Do.
Missouri State Hospital no. 4, Farmington	Holstein, registered.
Missouri State Sanitarium, Mount Vernon	Holstein, registered and grade.
Moss, J. Sam, Columbia	Jersey, registered.
Palmer, Paul, Moscow Mills	Do.
Parminter, E. J. & Son, Lockwood	Guernsey, registered.
Penn, Syd, Troy	Jersey, registered.
Stevenson, H. R., Shawneetown	Do.
Stout, C. C., Lees Summit	Do.
Stuart, E. V., Lees Summit	Do.
Switzer, Henry, Brunswick	Holstein, registered.
Vaughn, L. E., Webb City	Guernsey, registered.
Walker & Weeks Eldon	Jersey, registered.

MONTANA

Ayrshire Dairy (H. B. Mitchell), Great Falls	Ayrshire, registered and grade.
Erickson, R. L., Great Falls	Holstein, registered and grade.
Fetscher, Arthur, Stevensville	Guernsey, registered.
Frost, C. P. and Daughter, Hamilton	Jersey, registered.
Lyman, E. F. & Sons, Great Falls	Holstein, registered and grade.
McKillip, Hugh, Hamilton	Jersey, registered and grade.
Shoemaker, F. M., Arlee	Jersey, registered.

NEBRASKA

Bloss, Burton & Sons, Pawnee City	Jersey, registered.
Cummings, Mrs. Sam & Sons, Tecumseh	Holstein, registered.
Fairacres Farm, Winside	Do.
Haggart, Donald, Grand Island	Do.
Holling, Henry, Millard	Do.
Kearney, C. M. & Sons, Morrill	Jersey, registered.
Lohman, Wm., Jansen	Holstein, registered.
Mayer, J. A., Auburn	Holstein, registered and grade.
Moore, O. W., Gering	Holstein, registered.
Moyer, C. M., Ceresco	Do.
Norfolk State Hospital, Norfolk	Do.
Rabeler, Alex, Leigh	Guernsey, registered.
Ramsay, Roland & Shelby, Seward	Holstein, registered.
Rediger, Joseph, Milford	Guernsey, registered.
Rhodes, John, Beatrice	Jersey, registered.
Schumacher, Leo, Minatare	Holstein, registered and grade.
Severe, H. L., Palmyra	Do.
Shalla, Joseph, Odell	Do.

Swanson, F. A., Stromsburg	Holstein, registered and grade.
Thayer, D. D., Monroe	Do.
Walnut Springs Jersey Farm (Hershner & Stinnette), Lincoln.	Jersey, registered.
Wittrock, H. C., Falls City	Holstein, registered and grade.

NEW HAMPSHIRE

Benson, Maurice, Lebanon	Ayrshire, registered.
Hunter, Roy D., West Claremont	Jersey, registered.
Smith, Homer & Son, Monroe	Jersey, registered and grade.
Stearns, N. F., Lebanon	Do.
Sullivan County Home, Unity	Holstein, registered.

NEW JERSEY

Atkinson, Thomas, Bridgeton	Guernsey, registered and grade.
Blau, August & Son, Hackettstown	Holstein, registered.
Blossom Hill Farm, Lebanon	Do.
Borden, Herbert, Mickleton	Guernsey, registered.
Bordentown Industrial School, Bordentown	Holstein, registered.
Broadview Farms, Blawenburg	Guernsey, registered and grade.
Colson, Jessie, Daretown	Guernsey, registered.
Coombs, George A., Deerfield	Holstein, grade.
Cortwright, H. R., Port Jervis (N. Y.)	Holstein, registered.
Davis, C. V. N., Somerville	Holstein, registered and grade.
Davis Bros., Sewell	Holstein, grade.
DeHarte, Sidney, Bellemead	Holstein, registered.
Duffield, Robert, Mullica Hill	Holstein, registered and grade.
Edwards, Henry, Mullica Hill	Holstein, registered.
Essex County Hospital, Cedar Grove	Do.
Everitt, H. F., Flemington	Do.
Featherer, J., Salem	Guernsey, registered and grade.
Forsgate Farm, Jamesburg	Holstein, registered.
Fuller, Mrs. Julia & Sons, Wallpack	Holstein, registered and grade.
Hamilton, William, Somerville	Do.
Harris, Lester, Hancocks Bridge	Holstein, registered.
Horner, A. & Son, Pemberton	Guernsey, registered and grade.
Jackson, A. R., Columbus	Holstein, registered.
Katzenstein, G., Andover	Holstein, registered and grade.
Katzenstein, J., Hamburg	Do.
Kincaid, Herbert, Jefferson	Do.
Kirby, Charles, Harrisonville	Do.
Leonard, H. C., Paulsboro	Do.
Locust Lane Farm, Medford	Guernsey, registered.
Masonic Home, Burlington	Holstein, grade.
Morris County Welfare Farms, Morristown	Do.
Pettit, Frank, Woodstown	Holstein, registered.
Phillips, Edward, Cape May	Guernsey, registered and grade.
Price, Lester, Lafayette	Holstein, registered and grade.
Renne, F., Bridgeton	Do.
Rogers, Joseph, Wrightstown	Guernsey, registered and grade.
Roberts, Stanley, Port Jervis (N. Y.)	Holstein, registered.
Royce, George, Columbus	Jersey, registered and grade.
Rush, Charles T., Phillipsburg	Holstein, registered and grade.
Schanzlin, Hans, Washington	Holstein, registered.
Schellenger, Newton, Green Creek	Holstein, registered and grade
Skinner, Russell, Mullica Hill	Holstein, registered.
Spear, John, Rockaway	Guernsey, grade.
Stelle, W., Dutch Neck	Holstein, registered and grade.
Struble, H. & Son, Sussex	Do.
Ten Eyck, J. A., Pluckemin	Do.
Tranquility Farms, Tranquility	Holstein, registered.
Trenton State Hospital, Trenton	Holstein, registered and grade.
Van Nuys, P. P., Bellemead	Holstein, registered.
Vineland Training School, Vineland	Holstein, registered and grade.

Voegtlen, W., Lebanon	Holstein, registered.
Waddington, Arthur, Woodstown	Holstein, registered and grade.
Willard, Gardiner, Mullica Hill	Do.
Willow Gate Farm, Princeton	Do. Jersey, registered and grade.
Wolfe Bros., Hackettstown	Holstein, registered and grade.

NEW YORK

Andrews, G. S. V., LaGrangeville	Registered Holstein.
Beckwith, Earl A., Ludlowville	Registered Jersey.
Burdick, J. M., Little Valley	Registered Holstein.
Cowles, G. S. & Son, Ashville	Do.
Crocker, Earl D., Sennett	Registered Guernsey.
Cross, Roger H., Fayetteville	Registered Holstein.
Cuddy, M. J., Auburn	Do.
Cantine, Holly (Valley Farm), Saugerties	Do.
Fisher, A. & Sons, Canastota	Do.
Fisher, Carl, Cazenovia	Do.
Fortune, W. W., Sussex, N. Y	Do.
Ham, John M., Millbrook	Do.
Ham, Eugene, Verbank	Do.
Hartshorn, Karl & Son, Lebanon	Do.
Heinaman, Edward, Bath	Do.
Homestead Farms, Inc., Stormville	Do.
Hubbs, H., Kirkville	Do.
Johnson, Arthur, Caledonia	Do.
Kahler & Howland, R. D. 1, Elmira	Do.
LaMotte, L. V., Freeville	Do.
Maxon, W. R., Watertown	Do.
Mertz, Henry, New Paltz	Do.
Metropolitan Life Insurance Co., Wilton	Registered Ayrshire.
Morgenthau & Hoose, Hopewell Junction	Registered Holstein.
Morrisville State School, Morrisville	Do.
Morris, D. W., & Sons, West Winfield	Do.
Neilitz, Fred J., R. D. 1, Corning	Do.
Nichols, Ransom, Fort Edward	Do.
Palmer, Ada L., Hannacroix	Registered Guernsey.
Phillips, C. B. & Son, Ellicottville	Registered Ayrshire.
Plankenhorn, Herman, Hyde Park	Registered Holstein.
Porter, Fred L., Crown Point	Registered Ayrshire.
Price, George (estate), Livonia	Registered Holstein.
Randall, C. M., Gouverneur	Do.
Rogers, Wm., Oxford	Registered Guernsey, also grade.
Rowley, A. M. & W. H., Gouverneur	Registered Ayrshire.
Schoonmaker, Clarence, Gardiner	Registered Holstein.
Schoonmaker, John L., Accord	Do.
Smith, Maynard L., Elmira	Do.
Smith, W. J., Sheds	Do.
Thomas, Clayton P., Glens Falls	Registered Jersey.
Wait, H. R. Co., Auburn	Registered Holstein.
Wells, J. Sloat, Elmira	Do.
West Bros., Wellsboro	Do.
Young, James, Angelica	Do.

NORTH CAROLINA

Biltmore Farms, Biltmore	Jersey, registered.
Granada Farms, Granite Falls	Do.
Klondike Farms, Elkin	Guernsey, registered.
Mills Home, Thomasville	Holstein, registered.
Osborne Farms, Canton	Guernsey, registered.
Pinehurst Farms, Pinehurst	Ayrshire, registered.
Quail Roost Farms, Rougemont	Guernsey, registered.
Reynolds Lybrook Farms, Advance	Red Polled, registered.
Shuford, R. L., Newton	Jersey, registered.

Christianson, John, New Salem	Holstein, registered.
Holle, Fred C., New Salem	Do.
Holle, Henry W., Youngtown	Do.
Klusman, Chas. A., New Salem	Do.
Klusman, Henry, Youngtown	Do.
Klusman, John, Youngtown	Do.
Kroeger, Fred, Youngtown	Do.
Micheals, Fred C., Youngtown	Do.
Neas, Wm., New Salem	Do.
North Dakota Penitentiary, Bismarck	Holstein, registered and grade.
Schwarting, Henry, New Salem	Do.
Tellman, Edward, New Salem	Do.

OHIO

Aegeter, Bartley, Hanoverton	Holstein, registered.
Allwardt, Martin, Gibsonburg	Guernsey, registered.
Aigler, R. J., Bellevue	Do.
Alexander & Trout, Spring Valley	Jersey, registered.
Arps, Geo. W., Defiance	Do.
Ault, Joseph, Perrysburg	Holstein, registered.
Bailey, L. P., Co., Tacoma	Jersey, registered.
Bandy, John W., Bellevue	Guernsey, registered.
Barr, W. B. & Son, R. R. 3, Canton	Holstein, registered.
Biddle, W. L., & Son, Wauseon	Do.
Bieger, Benj., Burton	Jersey, registered.
Black, F. B., Route 6, Mansfield	Guernsey, registered.
Brosius, Corwin, Route 2, Hamilton	Holstein, registered and grade.
Cavanaugh Bros., Burton	Holstein, registered.
Cockley, W. B., Route 2, Lexington	Do.
Erf, Wm., Bellevue	Guernsey, registered.
Ernsthausen, C. W., Elmore	Holstein, registered.
Eustis, Mrs. Geo. D., Madisonville	Jersey, registered.
Evans, Ellis, Newark	Ayrshire, registered.
Francisco, Ed., Atwater	Holstein, registered.
Gates, R. D., Chardon	Guernsey, registered.
Hartley, Alva B., Barnesville	Jersey, registered.
Heifner, C. B. & Son, Sullivan	Guernsey, registered.
Hinman, Ralph, Ravenna	Jersey, registered.
House, Carl, Camden	Do.
Howell, Folger B., Springfield	Holstein, registered.
Ingersoll, H. W., Elyria	Jersey, registered.
Leas, Bert, Jr., Groveport	Do.
Lee, N. W. & Son, New London	Holstein, registered.
Lloyd Bros., Lebanon	Jersey, registered.
McClellan, F. H. & Son, Wellington	Do.
McHenry, J. W., Grafton, Route 2	Do.
Miller & Truman, Castalia	Guernsey, registered.
Murphy, J. O., Barnesville	Jersey, registered.
Nichols, A. J., Berlin Heights	Do.
Riehle, E. A., Edgerton	Holstein, registered.
Roland, Frank, New London	Jersey, registered.
Rose, S. B., Findlay, Route 3	Do.
Rupert, Willis, New Waterford	Do.
Schaff Dairy, Columbus	Holstein, registered.
Schleppi, Floyd, Columbus	Jersey, registered.
Scudder, Mrs. Charles, Buena Vista	Ayrshire, registered.
Sellers, Russell, Mount Vernon	Jersey, registered.
Siddal, C. B., Atwater	Holstein, registered.
Treat, Henry W., Tallmadge	Guernsey, registered.
Van Schyck, Ray, Hilliards	Holstein, registered.
Van Winkle, R. E., Newton Falls	Jersey, registered.
Voeller, Earl H., Grove City	Ayrshire, registered.
Weingart, Ben., Leetonia	Jersey, registered.
Wisler, A. E., Leetonia	Guernsey, registered.
Westrick, J. T., Defiance	Holstein, registered.
White, Fred, Galena	Jersey, registered.

Williams, H. F., Monroeville	Guernsey, registered and grade.
Wise, H. A., Versailles	Guernsey, registered.
Wood, Frank & Sons, Perry	Jersey, registered.
Yauger, A. W., Mount Vernon	Do.

OKLAHOMA

Griffith, C. E., Big Cabin	Holstein, registered.
Quinlan, C. P., Tulsa	Jersey, registered.

OREGON

Aasen, Olaf, Arago	Jersey, registered.
Dickson, J. M. & Son, Shedd	Do.
Fullenwider, Geo., Carlton	Do.
Geinger, John, Tillamook	Guernsey, grade.
Hagg Bros., Reedville	Jersey, grade.
Hampton, George, Arago	Jersey, registered.
Hense, Walter, Shedd	Do.
Iliff, Harry, Independence	Do.
Jose & Perrine, Tillamook	Guernsey, registered and grade.
Kay, Alton, Coquille	Jersey, registered and grade.
Scherer, Earl, Shedd	Jersey, registered.
Tibbles, M. N., Independence	Do.
Tupper, Alan, Carlton	Do.
Williams, Tom, Forest Grove	Do.
Zwald, Alfred, Tillamook	Do.

PENNSYLVANIA

Allebach, H. D., Trappe	Holstein, registered.
Allen, C. F., Dayton	Jersey, registered and grade.
Allen, Cordie, Nicholson	Holstein, registered.
Allen, Curtis, Nicholson	Holstein, registered, grade, and mixed.
Allegheny Work House, Blawnox	Jersey, grade.
Allegheny County Home, Woodville	Holstein, registered.
Allentown State Hospital, Allentown	Do.
Arnold Bros., Beaver Falls	Guernsey, registered.
Auker, T. R., Mifflintown	Holstein, registered.
Bagshaw, K. S., Hollidaysburg	Brown Swiss, registered.
Bagshaw, M. C., Hollidaysburg	Do.
Baily, A. L., Gladwyne	Jersey, registered.
Baker, J. D., Grove City	Do.
Bamford, Robert, & Son, Midway	Do.
Barkley, W. T., Livermore	Guernsey, grade.
Bauer, John, Emporium	Holstein, registered.
Beaver, George B., Millerstown	Do.
Bedford County Jersey Bull Association, Bedford.	Jersey, registered and grade.
Bellas, J. C., & Son, Harmony	Holstein, registered and grade.
Bence, C. D., Marion Center	Jersey, registered and grade.
Benner, H. K., Vicksburg	Holstein, registered and grade.
Bernherstl, Harvey N., Greenpark	Do.
Bicknell, Harry J., Pottstown	Holstein, registered.
Bieler, Mrs. Howard, East Greenville	Holstein, registered and grade.
Black, Jonothan R., Millerstown	Holstein, registered.
Black, N. E., Alexander	Guernsey, registered.
Blackburn Farm, Sewickley	Ayrshire, registered.
Blackman, Frank, Wattsburg	Holstein, registered and grade.
Blake, W. I., Mercer	Jersey, registered.
Bolton Farms, Bristol	Guernsey, registered.
Boak, J. A., & Sons, New Castle	Jersey, registered and grade.
Bowell, Arthur, Thompson	Holstein, registered.
Bowen, Roy L., Wellsboro	Do.
Bonson, C. William, Belleville	Holstein, registered and grade.
Brackman, John, Canton	Guernsey, registered.
Bonson, J. Clinton, Milroy	Holstein, registered and grade.

Bowen, Clark, Wellsboro	Holstein, registered.
Bradford, H. H., Lewistown	Do.
Briggs, J. S., Yardley	Guernsey, registered.
Brion, Ed. W., Liberty	Jersey, registered, grade, and mixed.
Brown, H. D. & T. J., South Montrose	Holstein, registered and grade.
Brown, H. E., Fairfield	Holstein, registered. Guernsey, grade.
Brown, Ray F., Mill Creek	Holstein, registered and grade.
Brownson, J. W., New Galilee	Jersey, registered.
Brubaker, M. V., New Holland	Holstein, registered.
Buck, L. E., Ulysses	Do.
Blum, Walter, Milanville	Holstein, registered and grade.
Brouse, Oscar, Mifflinburg	Brown Swiss, registered.
Bueckley, William, Cressona	Jersey, registered.
Bullers, A. J., Brookville	Guernsey, registered and grade.
Burchard, S. C., Burchardville	Jersey, registered.
Burkett, H. W., & Son, Tyrone	Guernsey, registered.
Burrows, D. N., Pleasantville	Holstein, registered and grade.
Butler, D. R., Knoxville	Guernsey, registered.
Butler, George B., Wellsboro	Guernsey, registered and grade.
Buss, C. L., Montgomery	Holstein, registered and grade.
Camp Discharge Farm, Conshohocken	Guernsey, registered.
Canby, J. P., & Son, Hulmerville	Holstein, registered. Jersey, registered and grade.
Card, Noel, Lawrenceville	Jersey, registered.
Carter, Claud L., Rush	Jersey, registered and grade.
Cessna, S. L., Bedford	Do. Holstein, registered.
Clarion County Guernsey Association, Clarion	Guernsey, registered and grade.
Cliffe, J. Howard, Ivyland	Guernsey, registered.
Cooper, Tom, & Son, Slippery Rock	Jersey, registered and grade.
Cope, F. R., Dimock	Holstein, registered.
County Home, Greensburg	Do.
Cox, T. R., Pulaski	Guernsey, registered and grade.
Coxe, Fred W., Everett	Jersey, registered.
Crissman, W. J., Lewistown	Holstein, registered.
Critchlou, Lee R., Harrisville	Jersey, registered and grade.
Culver, C. B., Laceyville	Holstein, registered and grade.
Delozier, J. M., Hollidaysburg	Brown Swiss, registered.
Deming, W. W., Millerton	Jersey, registered.
Dickey, R. N., Slippery Rock	Guernsey, registered.
Dinsmore, J. A., Washington	Jersey, registered.
Donaldson, R. M., Midway	Ayrshire, registered.
Doyle, Thomas, Dushore	Holstein, registered and grade.
Dreese, Palmer, McClure	Holstein, registered.
Dromgold, H. N., New Bloomfield	Holstein, registered and grade.
Dundee Farm, Sewickley	Guernsey, registered.
Edgar, C. F., Renfrew	Do.
Erdley, C. E., Lewisburg	Holstein, registered.
Erdley, W. J., Mifflinburg	Do.
Erdenheim Farm, Norristown	Jersey, registered.
Erk, George & Ed., Seelyville	Do.
Erk, Russell G., Prompton	Do. Holstein, registered.
Esterline, S. F., Greenburg	Jersey, registered and grade.
Erdley, W. S., Lewisburg	Holstein, registered.
Eshelman, Allen, Everett	Jersey, registered.
Fairacres Farm, Sewickley	Guernsey, registered.
Fairview Farm, Cornwall	Do.
Farmhill Dairy, Sewickley	Do.
Fernheim Farm, Montrose	Ayrshire, registered.
Fettig, Karl L., Port Royal	Holstein, registered.
Fisher, P. U. & Son, Rummersfield	Do.
Fleming, R. H., Troy	Do.
Frey, May, Ottsville	Jersey, registered.
Garland, Carl W., Buffalo Mills	Holstein, registered. Jersey, registered.

Garrison, W. E., Millerton	Guernsey, registered.
Gaut, J. C., Alverton	Holstein, registered and grade.
Gearhard, C. G., Blairsville	Do.
George, Walter, Lenhartsville	Holstein, registered.
Glen Foerd Farm, Torresdale	Ayrshire, registered.
Gorham, Claud S., LeRaysville	Jersey, registered.
Gray, H. I., Honey Grove	Holstein, registered.
Gregory, H. J., St. Marys	Do.
Grazier, H. E., Warriors Mark	Brown Swiss, registered.
Griffith Estate, Ebensburg	Guernsey, registered.
Grimms, W. S., Red Lion	Holstein, registered.
Groninger, H. E., Port Royal	Do.
Gross, E. S., Manchester	Guernsey, registered and grade.
Gross, Isaac, Plumsteadville	Holstein, registered.
Gruber, J. W. N., Shippenville	Guernsey, registered and grade.
Hallowell, Joseph W., Ivyland	Holstein, registered and grade.
Hamme, J. J., Abbottstown	Guernsey, registered.
Hauck, Clyde, Clymer	Jersey, registered.
Harrison, J. P., Centerville	Holstein, grade. Guernsey, grade.
Hasbrouck, Will, Titusville	Holstein, registered.
Havens, Geo. S., New Hope	Guernsey, registered.
Havenstein, W. F., Waymart	Jersey, registered.
Henderson, W. C., Petersburg	Brown Swiss, registered and grade.
Hopson, Fred, Wattsburg	Holstein, grade.
Hummer, A. K., Titusville	Holstein, registered.
Hummer, G. M., Titusville	Jersey, registered.
Hunsberger, Willis M., Plumsteadville	Holstein, registered.
Indiana County Home, Indiana	Holstein, registered and grade.
Inscho, J. H., Mansfield	Holstein, registered.
Irvin, Wm., Co., Big Run	Guernsey, registered.
Kane, Mrs. John Kent, Glenloch	Do.
Kaufman, Theo., Mifflintown	Holstein, registered.
Keen, Frank A., West Chester	Do.
Kimball, George & Son, Wattsburg	Holstein, registered and grade.
King, A. M., Mercer	Jersey, registered.
King, J. P. C., Summerville	Holstein, registered.
Koenig, John C. & Harry, Tarentum	Do. Guernsey, grade.
Koontz, C. E. & Son, Bedford	Jersey, registered.
Koontz, Stanley A., Bedford	Do.
Kost, Albert F., Carlisle	Holstein, registered.
Krall, Frank L. & Son, East Berlin	Do.
Kryder, T. C., Mill Hall	Do.
Leet, M. J. & Son, Coudersport	Do.
Lemon, J. M. & C. A., Saltsburg	Holstein, registered and grade. Jersey, registered.
Lent, Harry, Coudersport	Holstein, registered and grade.
Lichtenwalner, P. G., Emaus	Holstein, registered.
Lloyd, Wm. M., Downingtown	Jersey, registered.
Luce, R. W. & L., Guys Mills	Jersey, registered and grade.
Markey, S. H., Loysburg	Guernsey, registered.
Mahle, Howard, Miola	Guernsey, registered and grade.
Marshall, R. D., Beyer	Holstein, registered and grade.
Martin, H. K., Goodville	Do.
Martin, J. W. & Son, Bessemer	Jersey, registered.
Mashaming Farms, Newton	Ayrshire, registered.
Masonic Home Farms, Elizabethtown	Do.
Mattern, C. O., Osceola Mills	Guernsey, registered.
May, C. Allen, York	Do.
Mayes, J. Will, Howard	Do.
McCauley, W. M. & C. A., New Bethlehem	Holstein, registered.
McClelland Bros., Canonsburg	Do.
McClure, T. Furman, Port Royal	Do.
McCracken, A. L. & Sons, Charleroi	Jersey, registered and grade.
McCurley, H. L., Enon Valley	Do.

McDowell, G. G., Grove City	Jersey, registered and grade.
McIlvane, Lawrence, Bentleyville	Guernsey, registered.
McMillen, W. C., Home	Jersey, registered, grade, and mixed.
Mercer County Home, Mercer	Holstein, registered and grade.
Mercer Sanitarium, Mercer	Jersey, registered. Guernsey, grade.
Milhelm Bros., Sharon	Guernsey, registered and grade. Jersey, grade.
Mill Brook Farm, Mill Hall	Holstein, registered.
Miller, E. M., Towanda	Holstein, registered and grade.
Milligan, Ward R., Loysville	Do.
Mitchell, S. C., Lewistown	Holstein, registered and grade.
Moffat, John, New Alexandria	Guernsey, registered and grade.
Morgan, Wm., Wheelerville	Holstein, registered and grade.
Moheny, John, Punxsutawney	Guernsey, registered and grade. Jersey, grade.
Morrison, A. W., Eighty Four	Jersey, registered and grade.
Morrow, D. A., Tyrone	Guernsey, registered.
Morrison, D. H., Van	Guernsey, registered and grade.
Mourey, J. J., Lewistown	Holstein, registered.
Murphy, Harvey, Norristown	Holstein, grade.
Musser, C. A., Oakland Mills	Holstein, registered and grade.
Musser, R. E., Lewisburg	Holstein, registered.
Nicholson, S. L., Muncy	Do.
Norman, Albert, Liberty	Jersey, registered.
Oehrle, Frank, Hatboro	Holstein, registered.
Old Forge Farm, Spring Grove	Ayrshire, registered.
Oliver, H. Emmett, Honesdale	Holstein, registered and grade.
Oliver, T. H., Honesdale	Do.
Otto, Ivo V., Carlisle	Do.
Patton, J. S., Hartstown	Holstein, registered and grade.
Paulhamus, H. R., Cogan Station	Holstein, registered.
Paxison, Earl, Schuylkill Haven	Holstein, registered and grade.
Pearson, Wallace C., Downingtown	Jersey, registered.
Peffer, Clyde, Portersville	Guernsey, registered, grade, and mixed.
Pennsylvania Industrial School, Huntingdon	Holstein, registered.
Penshurst Farm, Narberth	Ayrshire, registered.
Perry, F. Morris, Charleroi	Jersey, registered.
Peters Brothers, Port Matilda	Holstein, registered.
Pew, J. W. (estate), Mercer	Guernsey, registered.
Polk State Hospital, Polk	Holstein, registered.
Pollock, C. C., Marion Center	Jersey, registered and grade.
Pruntsman, A. D., Millerstown	Holstein, registered.
Raab, Mrs. S. F. & Son, Dallastown	Holstein, registered and grade.
Reitz, J. L., Lewisburg	Do.
Reitze, Wesley, Meadville	Holstein, registered.
Rhein, L. E., Pine Grove	Jersey, registered.
Rishel, W. F., Center Hall	Holstein, registered.
Robbins, W. J., Beach Lake	Do.
Robinson, Henry A., Seelyville	Jersey, registered.
Roseway Farms, Paoli	Do.
Rude, W. E., Waymart	Jersey, registered and grade.
Rupp, Wm. H., Breinigsville	Holstein, registered.
Sage, E. H., Red Rock	Guernsey, registered and grade.
St. Vincent Archabby, Latrobe	Holstein, registered and grade.
Sampson, N. E., Volant	Jersey, registered.
Sampson, Ralph, Crooked Creek	Holstein, registered and grade.
Satterwaithe, Amos, Yardley	Holstein, registered.
Satterwaithe, Lewis, Newton	Do.
Satterthwaithe, M. C., Woodside	Do.
Schelman, Allen E., Everett	Jersey, registered.
Schott, Joseph H., Lebanon	Holstein registered.
Schuylkill County Alms House, Schuylkill Haven.	Ayrshire, registered.
Schwab, Mrs. Chas. M., Loretto	Guernsey, registered.

Seanar, J. H., New Alexandria	Holstein, registered and grade.
Schultz, Wayne, East Greenville	Holstein, registered.
Seiber, J. W., McAlisterville	Holstein, registered and grade.
Shaffer, E. W., Titusville	Guernsey, registered and grade.
Shaffer, Fred, Forksville	Holstein, grade.
Sheard, Russell, Milanville	Holstein, registered and grade.
Shook, Ray H., Sligo	Guernsey, registered.
Slifer, A. C., Lewisburg	Holstein, registered.
Smith, Carl F., McAlisterville	Do.
Smith, Ford, Millerton	Jersey, registered.
Smith, G. C., Martinsburg	Holstein, registered and grade.
Smith, Philip W., New Hope	Guernsey, registered and grade
Smith, Preston C., Martinsburg	Holstein, registered and grade.
Snedeker, Stephen, Waymart	Jersey, registered and grade.
Snyder, H. A., Montoursville	Holstein, registered.
Snyder, W. D., Coganstation	Do.
Snyder Bros., Liberty	Holstein, registered and grade.
Speeder, I. M., Livermore	Guernsey, registered and grade.
Speirs, James, Downingtown	Jersey, registered and grade.
Spencer, E. B. & Son, Millertown	Holstein, registered.
Stahl, Geo. D., Smithton	Holstein, registered.
State Industrial Home, Muncy	Holstein, registered and grade.
Stoltzfus, H. L., Pottstown	Holstein, registered.
Stoltzfus, Mart, Morgantown	Holstein, registered and grade.
Stouffer, C. D., Port Royal	Do.
Stover, John L., Ivyland	Holstein, registered and grade.
Summy, E. G., Mt. Pleasant	Holstein, registered and grade.
Swann, G. C., Home	Jersey, registered and grade.
Sycamore Farms, Douglassville	Ayrshire, registered.
Thompson, Lauren, New Wilmington	Jersey, registered.
Tioga County Farm, Wellsboro	Ayrshire, registered.
Torrance State Hospital, Torrance	Holstein, registered.
Towsend, Henry, South Bend	Guernsey, registered. Jersey, grade.
Travis, H. M., Smicksburg	Guernsey, registered and grade.
Tressler Orphans Home, Loysville	Holstein, registered and grade.
Tubbs, C. R., Turtlepoint	Do.
Twining, Wilmer A., Wycombe	Holstein, registered.
Uhl, Charles, Kersey	Ayrshire, registered and grade.
Ursinus College, Collegeville	Holstein, registered.
Walberg Bros., Kane	Mixed.
Walker, Carl, Marion Center	Jersey, registered and grade.
Walton, M. Hubert, New Hope	Guernsey, registered and grade.
Warren State Hospital, Warren	Holstein, registered and grade.
Warriner, C. W., Harrison Valley	Holstein, registered.
Weaner, Edgar, Gettysburg	Do.
Wehr, John S., Mifflinburg	Do.
Wellbee Farms, Wyalusing	Guernsey, registered.
Wentzel, H. B., Marion Center	Jersey, registered and grade.
Wentzel, W. M., Marion Center	Do.
Western Penitentiary, Bellefonte	Holstein, registered and grade.
Wetzel, H. H., Marion Center	Jersey, registered and grade.
Whittaker, Roy, Covington	Holstein, registered.
Wilkinson, C. L., Rushland	Holstein, registered and grade.
Williams, R. G. & Son, Canton	Holstein, registered.
Weyhill Farm, Bethlehem	Holstein, registered and grade. Guernsey, registered.
Wilson, Angus, Punxsutawney	Jersey, registered and grade.
Winey, Earl G., Middleburg	Guernsey, registered.
Wingert, A. C., Mechanicsburg	Holstein, registered.
Wohlwend, I. C., Salina	Brown Swiss, registered.
Wolf Creek Farm, Slippery Rock	Guernsey, registered.
Wood, J. L. & Son, Red Hill	Holstein, registered and grade.
Worley, C. M., Mercer	Guernsey, registered.
Wright, Willard W., Yardley	Holstein, registered and grade.
Yoder, Amos C., Allensville	Guernsey, registered and grade. Jersey, grade.

Zeigler, J. S., Lewisburg	Holstein, registered and grade.
Zimmermann, L. A., Lehighton, R. 1	Holstein, registered.
Zook & Son, Mifflintown	Do.

SOUTH CAROLINA

Caldwell, R. B., Chester	Guernsey, registered.
McCall, C. S., Bennettsville	Do.
Montgomery, V. M. (estate), Spartanburg	Holstein, registered.
Pedigreed Seed Co., Hartsville	Guernsey, registered.
South Carolina State Hospital, Columbia	Holstein, registered.

SOUTH DAKOTA

Ibsen, J. B., Viborg	Holstein, registered.
Jesperson, N. C., Viborg	Holstein, registered and grade.
Oviatt, Thad, Huron	Holstein, registered.
South Dakota Penitentiary Farm, Sioux Falls	Do.
State School and Home, Redfield	Do.
Yankton State Hospital, Yankton	Do.

TENNESSEE

Fort, R. E., Nashville	Jersey, registered.
Knapp School of Country Life, Nashville	Holstein, registered.
Waters, Henry, Greenwood	Jersey, registered.

TEXAS

Maverick, J. S., San Antonio	Holstein, registered. Jersey, registered.
Nixon, P. I., San Antonio	Do.
Price Dairy Farm, Vinton	Holstein, registered.
Shelton Bros., Brownwood	Jersey, registered.
Soverign Camp W. O. W., San Antonio	Do.
Wipprecht, Carl, Bryan	Do.

UTAH

Knudsen, Heber & Sons, Provo	Jersey, registered.
Rasband Bros., Heber	Do.
Utah State Mental Hospital, Provo	Holstein, registered.
Utah State Industrial School, Ogden	Do.

VERMONT

Allen, Ray, South Hero	Guernsey, registered.
Arms, W. C., Burlington	Jersey, registered and grade.
Bicknell Hill Farm, Tunbridge	Do.
Bigelow, A. P., Middlesex	Holstein, registered.
Brandon State School, Brandon	Do.
Brigham Farm, St. Albans	Jersey, registered.
Brookside Farm, White River Junction	Do.
Burbank, John, Chelsea	Do.
DeVine, Ernest, Ferrisburg	Guernsey, registered.
Field, K. S., Vergennes	Do.
Fisher, C. W., Vergennes	Do.
Gates Farm, North Hartland	Jersey, registered and grade.
Goodrich, W. I., West Danville	Jersey, registered.
Hager, W. C., Wallingford	Ayrshire, registered.
Hathorn, George B., White River Junction	Holstein, registered.
Howard Bros., White River Junction	Jersey, registered and grade.
Howe, L. W., Burlington	Holstein, registered.
Hutchinson Farm, Tunbridge	Jersey, registered.
Johnson, M. A., & Son, Middlebury	Holstein, registered.
Kingsbury, A., Cavendish	Guernsey, registered and grade.
Kurn Hattin Home, Westminster	Ayrshire, registered.
Landon, C. H., New Haven	Holstein, registered.
Lexington Farms, Reading	Jersey, registered.
Luce, H. E. & W. J., South Pomfret	Do.

Merrill, H. J., & Son, Williston	Holstein, registered and grade.
Mills, A., Florence	Guernsey, registered and grade.
Moore, Mrs. E. H., Pomfret	Jersey, registered.
Nelson, F. B., & Son, Salisbury	Jersey, registered and grade.
Palmer, R. W., Middlebury	Jersey, registered.
Perkins, Chas., Brattleboro	Guernsey, registered.
Phillips, J. A., Middlebury	Holstein, registered.
Ranney, R. H., Putney	Jersey, registered and grade.
Ranney, W. F., Westminster	Do.
Reed, C. L., Vergennes	Guernsey, registered and grade.
Salmon Bros., Glover	Ayrshire, registered.
Sheldon, G. & W., Jeffersonville	Jersey, registered and grade.
Simpson Farm, East Craftsbury	Jersey, registered.
Smith, A. L., & Son, Barre	Guernsey, registered.
Smith, Dana M., Lyndonville	Jersey, registered and grade.
Smith, G. W., Tunbridge	Do.
Somers, John, West Barnet	Do.
Thomas, O. A., Rutland	Holstein, registered.
Tucker, H., Tunbridge	Jersey, registered.
Upway Farm, South Woodstock	Do.
Vermont State Hospital Farm, Waterbury	Holstein, registered.
Whitcomb, W. D., Springfield	Guernsey, registered and grade.
White, Ralph W., Danville	Jersey, registered and grade.

VIRGINIA

Andrews, Dr. J. S., Orange	Jersey, registered.
Civil, Otto, Midlothian	Guernsey, registered.
Clover Hill Farm, Manassas	Jersey, registered and grade.
Crowgey, L. J., Wytheville	Holstein, registered.
Greendale Stock Farm, Roanoke	Holstein, registered and grade.
Hill, R. F., Jr., Orange	Jersey, registered and grade.
Hillandale Farm, Purcellville	Guernsey, registered and grade.
Hollins College, Hollins	Holstein, registered.
Kenilworth Farm, McLean	Guernsey, registered.
Lee, Dr. Geo. B., Burke	Holstein, registered and grade.
McComb Bros., Bluemont	Do.
McGee, James, Fredericksburg	Jersey, registered and grade.
Middleton, Ben & Sons, Herndon	Holstein, registered and grade.
Mistr, A., & Sons, Richmond	Guernsey, registered and grade.
Moyer, Chas., Mattoax	Holstein, registered and grade.
Nelson, R. N., Sr., Richmond	Jersey, registered and grade.
Patrick, H. T. Rustburg	Do.
Pemberton, Mrs. Eva, Richmond	Holstein, registered and grade.
Roller, J. S. & Paul, Timberville	Jersey, registered and grade.
Rowland, Wm., Warrenton	Guernsey, registered.
Salisbury, R. F., Fairfax, R 2	Do.
Sands, D. C., Middleburg	Do.
Saunders & Myers, Leesburg	Guernsey, registered and grade.
Taylor, J. P., Orange	Holstein, registered.

WASHINGTON

Allen, H. L., & Co., Duvall	Jersey, registered and grade.
Bass, Dan, Seattle	Guernsey, registered and grade.
Cedargreen, W. O., Snohomish	Holstein, registered.
Cloverfields Farm, Olympia	Jersey, registered and grade.
Cooke, Walter, Shelton	Jersey, registered.
Durrah, F. A., Grays River	Jersey, registered and grade.
Fishback Bros., Chehalis	Jersey, registered.
Hughes, D. R., Yelm	Guernsey, registered and grade.
Lilja, Victor, Stanwood	Do.
Porter, J. A., Custer	Jersey, grade.
Reilly, A. H., Waukon	Holstein, registered.
Scudder, Lucy R., Yakima	Guernsey, registered and grade.
Starr, Chas., Olympia, R. 1	Jersey, registered.
State Training School, Chehalis	Holstein, grade.
Stolt, George, Rochester	Guernsey, registered and grade.

Taylor, J. H., Montesano	Jersey, registered.
Taylor, Guy, R. 3, Olympia	Jersey, registered and grade.
Ticknor, R. B., Centralia	Guernsey, registered and grade.
Valley Gem Farm, Arlington	Guernsey, registered.
Waikiki Farm, Spokane	Holstein, registered
Western State Hospital, Fort Steilacoom	Do.
Wivell, Chas. H., Shelton	Jersey, registered.
Youngquist, Emil, Mount Vernon	Holstein, registered.
Youngquist, J. W., Bow	Do.

WISCONSIN

Baker, T. W., Waunakee	Holstein, registered.
Columbia County Asylum, Wyocena	Do.
Curtiss, W. W., Rio	Do.
Douglas County Asylum, Itasca	Holstein, registered and grade.
Dreger, Emil, R. F. D. 6, Madison	Holstein, registered.
Fowler, L. S., & Son, Bristol	Do.
Friday, John, Oregon	Do.
Gillmore, R. J., Bristol	Do.
Hausman & Wilcox, Knapp	Do.
Jacobson, Anton, Menomonie	Do.
Jensen, Chris, Colfax	Do.
Jeune, John L., Rice Lake	Do.
Krusescher, Roy, Union Grove	Do.
Lutheran Home Farm, Stoughton	Do.
Nichols, Morris, R. 2, Stoughton	Guernsey, registered.
Pester, Clarence & John, Whitewater	Holstein, registered.
Peterson, G. L., & Son, Sharon	Do.
Rock County Farm, Jonesville	Do.
Steffanus, Philip, DeLavan	Jersey, registered.
Thacher, C. B., Clear Lake	Guernsey, registered.
Trumpy, Frank, Clarno	Holstein, registered.
Weber, Fred, Bloomer	Do.
Wild Brothers, Elmwood	Guernsey, registered and grade.
Wisconsin School for the Blind, Janesville	Holstein, registered.
Zimmerman, Sam, Belleville	Do.

WYOMING

State Farms, Archer	Holstein, registered and grade.

College Herds

Alabama Polytechnic Institute, Auburn	Jersey.
University of Arkansas, Fayetteville	Holstein and Jersey.
University of Arizona, Tucson	Do.
University of California, Davis	Do.
Colorado State College of Agriculture, Fort Collins.	Guernsey and Holstein.
Connecticut State College, Storrs	Ayrshire, Guernsey, Holstein, and Jersey.
University of Delaware, Newark	Holstein.
University of Georgia, Athens	Guernsey, Holstein, and Jersey.
Georgia Coastal Plain Experiment Station, Tifton.	Jersey.
University of Idaho, Moscow	Holstein.
Agricultural Experiment Station, Purdue University Lafayette, Ind.	Holstein and Jersey.
University of Illinois, Urbana	Ayrshire, Brown Swiss, Holstein, and Jersey.
Iowa State College Ames	Guernsey, Holstein, and Jersey.
Kansas State College of Agriculture, Manhattan.	Ayrshire.
Kentucky Experiment Station, Lexington	Holstein and Jersey.
Louisiana State University, Baton Rouge	Do.
Louisiana State Normal College, Natchitoches	Jersey.
North Louisiana Experiment Station, Calhoun	Do.
Southwestern Louisiana Institute, Lafayette	Do.

Maryland Experiment Station, College Park	Ayrshire.
Massachusetts State College, Amherst	Ayrshire, Guernsey, Holstein, Jersey, and Shorthorn.
Upper Peninsula Experiment Station, Chatham, Mich.	Holstein.
Michigan State College, East Lansing	Do.
University of Minnesota, St. Paul	Holstein and Jersey.
Mississippi State College, State College	Jersey.
University of Missouri, Columbia	Holstein and Jersey.
Montana State College, Bozeman	Do.
University of Nebraska, Lincoln	Holstein.
University of Nebraska Experiment Station, North Platte.	Do.
Nebraska School of Agriculture, Curtis	Do.
University of New Hampshire, Durham	Holstein.
New Jersey Experiment Station, New Brunswick.	Holstein.
New Jersey Experiment Station, Sussex	Do.
New York Agricultural Experiment Station, Geneva.	Jersey.
New York Agricultural Experiment Station, Cornell University, Ithaca.	Holstein.
New Mexico College of Agriculture and Mechanic Arts, State College.	Do.
North Carolina Department of Agriculture (Coastal Plains), Raleigh	Jersey.
North Carolina State College, Raleigh	Do.
North Dakota Agricultural College, Fargo	Holstein.
Trumbull County Experiment Station, Cortland, Ohio.	Do.
Ohio Experiment Station, Wooster	Jersey.
Oklahoma Agricultural and Mechanical College, Stillwater.	Jersey, Ayrshire, and Holstein.
Oregon State College, Corvallis	Ayrshire, Holstein, and Jersey.
Pennsylvania State College, State College	Holstein.
Rhode Island State College, Kingston	Do.
Clemson Agricultural College, Clemson College.	Guernsey, Holstein, and Jersey.
South Dakota State College of Agriculture, Brookings.	Do.
University of Tennessee, Knoxville	Holstein.
Tennessee Polytechnic Institute, Cookeville	Jersey.
Texas Agricultural and Mechanical College, College Station.	Holstein and Jersey.
Texas Agricultural Experiment Station, College Station.	Jersey.
Utah State College, Logan	Holstein and Jersey.
Utah State Experiment Station, Logan	Holstein.
Vermont Agricultural Experiment Station, Burlington.	Ayrshire, Guernsey, and Jersey.
Virginia Polytechnic Institute, Blacksburg	Guernsey, Holstein, and Jersey.
Virginia Agricultural Experiment Station, Blacksburg.	Holstein.
West Virginia University, Morgantown	Do.
Washington State College, Pullman	Do.
Western Washington Experiment Station, Puyallup.	Do.
University of Wisconsin, Madison	Do.
University of Wyoming, Laramie	Guernsey and Holstein.
Department of State Experiment Farms, Afton, Wyo.	Holstein.

Bureau of Dairy Industry Herds

Bureau of Dairy Industry, Beltsville, Md., Huntley, Mont., and Woodward, Okla.

Summaries of What the Survey Showed for Selected Herds in Which Progress is Being Made in Breeding Superior Germ Plasm for Producing Ability

Following are herd summaries for some of the herds in this survey that have shown progress in breeding superior germ plasm for producing ability.

The herds have been grouped according to the number of proved sires, since it is recognized that the larger the number of sires used, the greater the chance of having used some sires that were not up to standard. It would also have been desirable to subdivide these groups according to the level of production. In some cases corrections were made for environmental conditions, in other cases not. Some were corrected from three milkings to two, others from two milkings to three. Since sire ratings were made on the basis of percentages of increase or decrease, level of production does not enter into the picture except for the relation of the level of production of the dams to the average of the herd; but this, too, is expressed as a percentage. In studying these summaries, therefore, too much emphasis should not be put on the level of production.

It is to be regretted that space does not permit the inclusion of a more detailed report on these herds, such, for instance, as the summary of each herd that is being sent to each cooperator.

The letters in the columns headed percent, milk, and butterfat indicate the merit of the corresponding sires used in the herd. If it is a three-sire herd and under percent—reading from top to bottom—the letters E, G, G appear, this indicates that these three sires, in the order used in the herd, each possessed an inheritance for percentage of butterfat that was much higher than the average of the dams to which they were mated. If under milk the reading was P, G, E, it indicates that the first sire's inheritance for milk yield was below the level of the dams with which he was mated but that the next two sires had an inheritance that was decidedly better than the dams to which they were mated. If in the column for butterfat yield the three sires rated G, G, G, it would indicate that these sires each possessed an inheritance for butterfat yield that was considerably higher than the dams with which they were mated. The greater the number of pairs for each sire the more reliable the rating should be.

If there are any female lines of descent in the herd that carry crosses of each of these three sires, good progress has been made in these strains toward fixing an inheritance higher than the level of the dams, under the environmental conditions that existed in the herd. If there are only two female lines of descent with two crosses of proved sires in the herd, it would indicate that in spite of the fact that three proved sires have been used, there are no female lines carrying the crosses of all three, and only a limited number of female lines with crosses of two of the three sires. In this case very little progress has been made in the herd in concentrating or piling up the superior inheritance possessed by the three sires. These female lines with two crosses may or may not carry a cross of the sire that rated P for milk yield.

If the number of pairs by not-proved sires is large in proportion to the number of pairs by meritorious proved sires, it may indicate that a considerable proportion of the germ plasm of the herd comes from those sires for which no attempt was made to gage the inheritance because of the limited amount of data. The herd average gives an idea of the level of production in the herd under the existing environmental conditions. The environmental conditions are given a very limited description in the line with the caption Conditions. The line for Herd average includes the records of all animals tested in the herd. The average yield of the daughters of the last sire is given on the next line.

In the lines giving number of female lines of descent with a given number of proved sires, the term "proved sires" means sires with the ratings given in the columns above, including those rated poor and undeterminable. The term "proved sire" as used here does not necessarily mean a meritorious sire. Proved sires in this report are sires with a sufficient number of daughter-dam pairs to justify evaluating their transmitting ability.

On page 1013, under the methods of evaluating germ plasm for producing ability, the interpretation and significance of the herd analysis, as presented in this appendix, has been pointed out. On page 1028, in the discussion of the results of the survey, there is also information that has a bearing on the interpretation of these summaries.

It would be well to repeat here that the letter E stands for Excellent, G for Good, F for Fair, P for Poor, U for Undetermined, and NP for Not Proved.

15-SIRE HERD

JOHN R. SIBLEY, SPENCER, MASS., JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	23	U	F	F	Spermfield Owl 57088.
3	27	F	P	P	Interested Prince 58224.
4	8	F	P	P	Model's Oxford Lad 66518.
5	7	U	P	P	Fontaine's Duke 61709.
6	9	P	F	P	The Owl's Double Grandson 80314.
7	6	P	G	F	Owl's Temisia's Owl 94772.
9	16	P	G	F	Sibley's Choice 83040.
10	13	E	P	F	Sibley's Interested Prince 108578.
11	14	P	G	G	Oxford Lad's Progress 92916.
12	5	F	F	G	Imported Financial Bacon 139499.
13	10	P	F	F	Sibley's Interested Owl 134069.
15	70	G	P	U	Spermfield Owl's Progress 163331.
16	10	E	P	F	Grace Darling's Choice Owl 200111.
18	5	E	P	P	Xenia's Prince 221324.
20	7	E	P	F	Mildred's Owl 199194.
8, 14, 17, 19	10	NP	NP	NP	
Total	240				
Number of daughters better than dams.		142	105	116	
		Percent	*Pounds*	*Pounds*	
Herd average of 363 cows		5.48	8,959	488	
Average of daughters by last sire.		6.20	8,762	547	

Conditions: 2 and 3 milkings corrected to 2 milkings.
1 female line with 6 successive crosses of proved sires.
6 female lines with 5 successive crosses of proved sires.
15 female lines with 4 successive crosses of proved sires.
29 female lines with 3 successive crosses of proved sires.
61 female lines with 2 successive crosses of proved sires.

11-SIRE HERD

MISSISSIPPI STATE COLLEGE, STATE COLLEGE, MISS., JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
	13	G	P	P	Prospects Polo 53072.
	19	P	G	U	Fox's Johnie O'Dreamwold 68143.
	16	P	P	P	Fox Glove's Eminent 90277.
9	14	P	E	E	Roycroft Eminent 103231.
12	14	P	F	F	Interested Prince's Owl 98117.
13	5	P	F	U	Roxia's Polo Fox 127777.
15	17	F	F	F	Osie's Pogis 230177.
18	22	G	E	E	Pogis 99th of Hood Farm 28th 138349.
19	15	G	G	G	Sarona's Oxford 186208.
21	9	P	P	P	Sophie's I. X. L. 244764.
22	6	P	P	P	Fairy Flag's Raleigh 267553.
1, 2, 3, 4, 8, 10, 11, 14, 16, 17, 20, 23, 24.	23	NP	NP	NP	
Total	173				
Number of daughters better than dams.		83	92	87	
		Percent	*Pounds*	*Pounds*	
Herd average of 180 cows		5.11	8,227	416	
Average of daughters by last sire.		5.26	6,745	355	

Conditions: Register of Merit, milkings not stated.
3 female lines with 7 successive crosses of proved sires.
8 female lines with 6 successive crosses of proved sires.
11 female lines with 5 successive crosses of proved sires.
11 female lines with 4 successive crosses of proved sires.
28 female lines with 3 successive crosses of proved sires.
9 female lines with 2 successive crosses of proved sires.

10-SIRE HERD

PRICE'S DAIRY FARM, VINTON, TEX., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
1	23	F	F	F	King Pontiac Joe Hengerveld 144623.
2	52	F	F	F	Prince Walker Pietertje Rhea.
3	54	G	F	G	King Pietertje Ormsby Piebe 42nd.
4	6	F	P	U	Prince Walker Rhea 462544.
5	6	G	G	G	Price America Hengerveld 462543.
6	19	G	P	P	Carnation Joe Segis Korndyke 514467.
7	6	F	G	E	Fred Ollie Pontiac Segis 426007.
8	5	E	P	F	Sir Pontiac Parthenea Ollie 514596.
11	5	E	P	P	Price Joe Ollie 610090.
12	7	E	P	P	Price Joe Segis Holmes 610087.
10	1	NP	NP	NP	
Total	184				
Number of daughters better than dams.		124	85	98	
		Percent	*Pounds*	*Pounds*	
Herd average 281 cows		3.42	17,315	591	
Average of daughters by last sire.		3.83	12,759	491	

Conditions: 3 milkings.
4 female lines of descent with 4 successive crosses of proved sires.
13 female lines of descent with 3 successive crosses of proved sires.
53 female lines of descent with 2 successive crosses of proved sires.

9-SIRE HERDS

WINTERTHUR FARMS, HENRY F. DU PONT, WILMINGTON, DEL., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	37	U	F	F	Sir Inka Prilly Segis 80914.
3	8	F	U	F	Uneeda King Alcartra 182646.
4	82	G	G	E	King of the Ormsby's 178078.
5	16	G	F	F	Johanna King Segis 71964.
6	31	F	F	F	Winterthur Bess Burke Best 300657.
7	28	G	G	E	Winterthur Bess Ormsby Boast 300652.
8	21	F	P	P	Winterthur Bess Ormsby Donsegis 400000.
9	28	G	G	E	Jemima Riverside Boast Ormsby Dad 406093.
10	21	F	G	G	Winterthur Bess Ormsby Great 500000.
Total	272				
Number of daughters better than dams.		190	161	178	
		Percent	*Pounds*	*Pounds*	
Herd average 397 cows		3.54	18,538	657	
Average of daughters by last sire.		3.69	21,650	802	

Conditions: 2, 3, and 4 milkings corrected to 3 milkings.
4 female lines of descent with 4 successive crosses of proved sires.
26 females line of descent with 3 successive crosses of proved sires.
80 female lines of descent with 2 successive crosses of proved sires.

9-SIRE HERDS—Continued

PONTIAC STATE HOSPITAL, PONTIAC, MICH., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
3	5	F	E	E	Bell Farm King Sylvia 297729.
4	8	F	F	F	Lakewood Ona King Pet Canary 375949.
5	5	P	F	P	Bell Farm Senator 408339.
7	29	P	F	P	Traverse Echo Sylvia Walker 456088.
8	14	F	E	E	Pontiac Butter Boy Eugene 476216.
10	22	G	F	G	Pontiac Butter Boy Hengeveld 495889.
11	13	G	G	E	Traverse Johanna Marathon Burke 540399.
12	9	P	P	P	Traverse Sylvia Marathon 504401.
13	10	F	F	F	Decreamco Bess Burke Hartog 573267.
2, 6, 9	9	NP	NP	NP	
Total	122				
Number of daughters better than dams.		64	72	72	
		Percent	Pounds	Pounds	
Herd average, 190 cows		3.25	14,611	474	
Average of daughters by last sire		3.35	14,686	489	

Conditions: Semiofficial and herd test, 3 milkings.
5 female lines of descent with 3 successive crosses of proved sires.
42 female lines of descent with 2 successive crosses of proved sires.

J. S. MAVERICK, SAN ANTONIO, TEX., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
4	6	E	F	G	Eminent of Park Terrace 126808.
5	16	E	E	E	Royal Majesty of Sunshine 143784.
6	13	P	U	P	Golden Jolly Oxford 116866.
7	33	P	P	P	Oxford Golden Sunshine 184728.
8	22	F	E	E	Achilles of Sunshine 208481.
9	20	F	F	G	Sophie's Village Knight 232205.
10	7	P	G	F	Sophie's Canyon of Foe 220222.
13	6	G	P	P	Sybil's Bay Boy 243804.
14	7	F	P	P	Sunshine Blonde 285825.
3, 11, 12, 15, 16, 17, 18, 19, 20, 21, 22	22	NP	NP	NP	
Total	152				
Number of daughters better than dams.		83	76	74	
		Percent	Pounds	Pounds	
Herd average, 198 cows		5.21	8,709	453	
Average of daughters by last sire		5.60	9,394	518	

Conditions: Milkings not given.
2 female lines with 6 successive crosses of proved sires.
4 female lines with 5 successive crosses of proved sires.
23 female lines with 4 successive crosses of proved sires.
51 female lines with 3 successive crosses of proved sires.
37 female lines with 2 successive crosses of proved sires.

MICHIGAN REFORMATORY, IONIA, MICH., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	6	G	E	E	King Segis Pontiac Canary 4th 175782.
3	6	U	U	F	Aaggie Bonastine Lorena 247128.
4	7	G	U	F	Echo Sylvia King Model 266177.
5	7	P	P	P	King Sadie Vale Pontiac Veeman 27[illegible]05.
7	32	P	F	U	Traverse Echo Sylvia Kaastra 343285.
8	6	F	F	G	New[illegible] Houwtje Segis Pontiac 40[illegible]
10	25	F	G	G	Ormsby Sensation 33rd 401108.
12	8	G	P	P	Traverse Marathon Netherland 522685.
14	6	P	P	P	Refo[illegible]ory King Cadilac Model 54[illegible]
1, 6, 9, 11, 13, 15, 16, 17	14	NP	NP	NP	
Total	117				
Number of daughters better than dams.		60	57	54	
		Percent	Pounds	Pounds	
Herd average of 156 cows		3.28	15,784	514	
Average of daughters by last sire		3.16	13,353	421	

Conditions: 3 and 4 milkings not adjusted.
8 female lines with 4 successive crosses of proved sires.
26 female lines with 3 successive crosses of proved sires.
50 female lines with 2 successive crosses of proved sires.

8-SIRE HERDS

UNIVERSITY OF IDAHO, MOSCOW, IDAHO, HOLSTEIN

Sire no.	Pairs of daughters and dams	Ratings of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
6	11	F	G	G	King Segis M
7	10	U	P	P	Friend Hen 258625.
8	10	U	E	G	Matador Vio
9	17	P	E	G	King Piebe I
10, 10A	9	P	E	E	Idaho Violet
11	6	F	E	E	Hazelwood I
14	12	P	G	G	Matador Seg
16	7	U	G	G	Sir Adna Pe
2, 3, 4, 5, 13	8	NP	NP	NP	
Total	90				
Number of daughters better than dams.		38	57	51	
		Percent	*Pounds*	*Pounds*	
Herd average of 97 cows		3. 29	19, 421	630	
Average of daughters by last sire.		3. 22	22, 916	736	

Conditions: 3 milkings.
1 female line with 6 successive crosses of proved sires.
2 female lines with 5 successive crosses of proved sires.
12 female lines with 4 successive crosses of proved sires.
24 female lines with 3 successive crosses of proved sires.
35 female lines with 2 successive crosses of proved sires.

TEXAS AGRICULTURAL EXPERIMENT STATION, COLLEGE STATION, TEX., JERSEY

Sire no.	Pairs of daughters and dams	Ratings of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
2	22	F	G	G	Sophie's Experimenter 137652.
3	11	P	E	G	Owl-Interest Experimenter 138518.
6	7	G	G	G	Grout's Masterman 240323.
7	11	E	P	P	Dahlia's Royal Knight 208433.
8	13	P	P	P	Sophie's Colonel 242169.
9	15	F	G	G	Experimentress' Knight 269318.
10	5	F	F	G	L. C. Oxford's Experimenter 294419.
11	7	P	G	G	Experimentress' Lad 291225.
4, 5	5	NP	NP	NP	
Total	96				
Number of daughters better than dams.		50	61	59	
		Percent	*Pounds*	*Pounds*	
Herd average of 129 cows		5. 35	6, 301	337	
Average of daughters by last sire.		5. 33	7, 399	395	

Conditions: 2 milkings.
1 female line with 6 successive crosses of proved sires.
1 female line with 4 successive crosses of proved sires.
10 female lines with 3 successive crosses of proved sires.
27 female lines with 2 successive crosses of proved sires.

PINEHURST FARMS, PINEHURST, N. C., AYRSHIRE

Sire no.	Pairs of daughters and dams	Ratings of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
II	36	G	P	P	O. T. B. Good 13550.
III	5	E	P	G	Favorite Crusader 20934.
IV	29	E	F	G	Marshall Mischief 24633.
V	7	P	E	G	Pinehurst Premier 30119.
VI	23	U	U	P	Pinehurst Masterpiece 28692.
VII	13	U	P	P	Pinehurst Lord Mitchell 24963.
VIII	9	F	F	F	Pinehurst King Pau 37716.
IX	9	G	G	G	Penshurst William Tell 41263.
I	0	NP	NP	NP	
Total	131				
Number of daughters better than dams.		90	63	67	
		Percent	*Pounds*	*Pounds*	
Herd average of 212 cows		4. 23	8, 941	376	
Average of daughters by last sire.		4. 31	8, 727	375	

Conditions: 2 and 3 milkings corrected to 2 milkings.
9 female lines of descent with 3 successive crosses of proved sires.
31 female lines of descent with 2 successive crosses of proved sires.

8-SIRE HERDS—Continued

LAPEER HOME AND TRAINING SCHOOL, LAPEER, MICH., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
1	6	G	G	E	Traverse Colantha Ryma Lad 190296.
2	8	P	E	E	Pontiac Lapier Burke Ormsby 247477.
3	6	F	E	E	Traverse Homestead Prince Echo 360093.
4	6	E	G	G	Kalamazoo Pontiac Lad 403089.
6	9	F	U	F	Traverse Lapier Colantha 483077.
7	11	F	F	G	Reformatory Kaastra 492873.
8	14	U	P	P	Pontiac Fayne Hengerveld 488552.
9	6	P	P	P	Traverse Marathon Burke Walker 588188.
5	2	NP	NP	NP	
Total	68				
Number of daughters better than dams.		36	34	33	
		Percent	*Pounds*	*Pounds*	
Herd average of 96 cows		3.32	13,344	443	
Average of daughters by last sire.		3.30	12,207	405	

Conditions: 3 milkings.
8 female lines of descent with 4 successive crosses of proved bulls.
21 female lines of descent with 3 successive crosses of proved bulls.
13 female lines of descent with 2 successive crosses of proved bulls.

NORFOLK STATE HOSPITAL, NORFOLK, NEBR., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	8	G	G	E	King Hartog Pontiac Boon 174249.
4	6	G	G	E	Varsity Derby Bond 212002.
5	11	F	E	E	Varsity Piebe La Valor 335128.
7	15	U	F	G	U. Nebraska Count Ormsby Sultan 415212.
9	19	F	F	F	U. Nebraska Count Ormsby Caesar 415211.
10	15	F	F	F	U. Nebraska King Gert 472479.
11	6	P	P	P	N. P. Beauty Gerben Hengerveld 360809.
13	7	P	P	P	U. Nebraska Segis Quinray 509124.
3, 6, 8, 12, 14	13	NP	NP	NP	
Total	100				
Number of daughters better than dams.		58	57	59	
		Percent	*Pounds*	*Pounds*	
Herd average of 126 cows		3.57	15,466	550	
Average of daughters by last sire.		3.35	16,300	542	

Conditions: 2 milkings, Dairy Herd-Improvement Association.
1 female line of descent with 4 successive crosses of proved sires.
16 female lines of descent with 3 successive crosses of proved sires.
34 female lines of descent with 2 successive crosses of proved sires.

UNIVERSITY OF NEBRASKA, LINCOLN, NEBR., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
8	6	F	F	F	King Segis Hengerveld Vale 60344.
10	9	E	G	E	King Derby Lincoln 153017.
13, 25	17	F	P	P	King Piebe Pontiac Segis 174303.
16, 22	13	G	U	F	Count Ormsby Segis Pontiac 338994.
19	6	E	F	F	Matador Violet Idaho —.
20	12	F	P	P	U. Neb. Klaver King 388329.
23	8	P	P	P	King Segis Violet Posch Idaho 224391.
28	9	P	F	P	U. Nebr. Matador Quantity 447735.
2, 3, 4, 5, 6, 7, 9, 11, 12, 14, 15, 17, 18, 24, 26, 27, 29.	34	NP	NP	NP	
Total	114				
Number of daughters better than dams.		63	51	51	
		Percent	*Pounds*	*Pounds*	
Herd average of 128 cows		3.62	17,807	645	
Average of daughters by last sire.		3.53	17,845	625	

Conditions: 2, 3, and 4 milkings adjusted to 3.
2 female lines with 4 successive crosses of proved sires.
15 female lines with 3 successive crosses of proved sires.
20 female lines with 2 successive crosses of proved sires.

8-SIRE HERDS—Continued

J. P. TAYLOR, ORANGE, VA., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of — Milk	Rating of sires: Production of — Butterfat	Name of sire
5	7	P	P	P	King Pontiac Ormsby DeKol 81252.
8	24	U	F	F	Major Butter Boy Korndyke 137803.
10	15	F	E	E	Jenningshurst Mutual Rag Apple 150690.
11	23	P	G	F	Hollins Hassett 22772.
13	38	F	G	G	D. C. D. P. Pontiac 381431.
14	65	F	F	F	King Ormsby Ideal Beauty 382746.
16	47	F	P	P	M. F. Sadie Vale Pontiac Joe 485606.
17	15	G	U	G	M. F. Ormsby Rex Ideal 538638.
3, 4, 7, 15, 18	11	NP	NP	NP	
Total	245				
Number of daughters better than dams.		136	120	124	
		Percent	*Pounds*	*Pounds*	
Herd average of 315 cows		3.44	11,626	398	
Average of daughters by last sire.		3.65	12,750	465	

Conditions: 2 milkings corrected to 365 days.
14 female lines with 5 successive crosses of proved sires.
46 female lines with 4 successive crosses of proved sires.
62 female lines with 3 successive crosses of proved sires.
48 female lines with 2 successive crosses of proved sires.

7-SIRE HERDS

VIRGINIA POLYTECHNIC INSTITUTE, BLACKSBURG, VA., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
D	10	P	E	F	Star Farm Johanna Lad 45225.
F	17	P	G	F	Virginia Korndyke Butter Boy 128445.
G	6	U	F	F	V. P. I. Buckeye Pauline Korndyke 193742.
H	11	U	E	E	Marathon Skylark Ormsby 312129.
I	15	F	F	F	Marathon Bess Burke 16th 375366.
J	5	P	G	F	Ormsby Sensation 45th 480493.
K	16	G	P	P	Rosni DeKol Homestead Veeman 154.
C	2	NP	NP	NP	
Total	82				
Number of daughters better than dams.		45	44	41	
		Percent	*Pounds*	*Pounds*	
Herd average of 107 cows		3.57	17,557	622	
Average of daughters by last sire.		3.61	16,004	575	

Conditions: 3 and 4 milkings.
1 female line with 6 successive crosses of proved sires.
4 female lines with 5 successive crosses of proved sires.
4 female lines with 4 successive crosses of proved sires.
10 female lines with 3 successive crosses of proved sires.
20 female lines with 2 successive crosses of proved sires.

J. S. ANDREWS, ORANGE, VA., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	5	F	F	G	Golden Spark of Montpelier 84576.
3	7	E	P	F	Hawthorne's Prince 104887.
4	5	E	P	G	Darling's Fancy Lad 134091.
5	7	P	G	F	Music's Torono 170406.
12	6	F	G	E	Pogis 99th of Hood Farm 54th 169653.
13	14	P	F	F	Rosalie's Interested Owl 259509.
17	7	E	P	F	Mary's Pogis of Andrewsia 308442.
6, 7, 8, 9, 10, 11, 14, 15, 16, 18	17	NP	NP	NP	
Total	68				
Number of daughters better than dams.		40	27	41	
		Percent	*Pounds*	*Pounds*	
Herd average of 84 cows		5.56	9,672	539	
Average of daughters by last sire.		6.14	9,473	585	

Conditions: 2 milkings corrected to 365 days.
2 female lines with 4 successive crosses of proved sires.
4 female lines with 3 successive crosses of proved sires.
25 female lines with 2 successive crosses of proved sires.

TEXAS AGRICULTURAL AND MECHANICAL COLLEGE, COLLEGE STATION, TEX. HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	10	U	P	P	Texas Aggie Korndyke 203846.
4	7	P	F	F	Jamaica King 160275.
5	11	P	F	P	Dutchland Aaggie Tidy Prince 2d 146528.
7	12	P	F	U	Nudine Tidy Prince 433729.
8	11	F	F	F	Grahamholm Dutchland Colantha 370759.
10	9	P	E	G	Nudine Princess Posch 548559.
11	16	G	F	F	Jewel Blanche Colantha Lad 515039.
3, 6, 9	5	NP	NP	NP	
Total	81				
Number of daughters better than dams.		40	46	45	
		Percent	*Pounds*	*Pounds*	
Herd average of 109 cows		3.24	15,861	506	
Average of daughters by last sire.		3.27	16,881	550	

Conditions: 3 milkings.
4 female lines with 4 successive crosses of proved sires.
13 female lines with 3 successive crosses of proved sires.
20 female lines with 2 successive crosses of proved sires.

KALAMAZOO STATE HOSPITAL, KALAMAZOO, MICH., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
1	11	E	G	E	King Pontiac Burke Alcartra 203224.
4	13	P	G	F	Traverse Echo Ormsby Model 430587.
5	13	G	U	F	Kalamazoo Pietertje Korndyke Lad 434862.
6	19	G	E	E	Sir Pietertje Hengerveld Lad 493589.
8	6	U	E	E	Traverse Buckeye Marathon Burke 542138.
11	6	P	E	G	Traverse Marathon Sylvia Burke 565365.
12	7	F	E	E	Traverse Colantha Echo Burke 579495
2, 7, 9, 10	10	NP	NP	NP	
Total	85				
Number of daughters better than dams.		51	61	62	
		Percent	*Pounds*	*Pounds*	
Herd average of 144 cows		3.47	13,147	456	
Average of daughters by last sire.		3.56	17,024	604	

Conditions: 3 milkings.
8 female lines with 3 successive crosses of proved sires.
30 female lines with 2 successive crosses of proved sires.

H. G. HASKELL, WILMINGTON, DEL., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
5	6	F	E	E	Golden Searchlight of Hill-Girt Farm 79310.
6	9	E	P	P	Merry Ne Plus Ultra of Hill-Girt 55746.
7	6	U	F	P	Longwater Guardsman 88297.
8	24	F	F	F	Noranda 108708.
9	6	E	P	P	Golden Toro 106686.
10	9	P	F	F	Longwater Mary's Royal 82716.
11	5	P	E	G	Merry Top of Hill Girt 137474.
2, 3, 4	10	NP	NP	NP	
Total	75				
Number of daughters better than dams.		46	45	41	
		Percent	*Pounds*	*Pounds*	
Herd average of 101 cows		5.17	12,339	633	
Average of daughters by last sire.		5.27	14,106	743	

Conditions: 3 milkings, advanced register.
1 female line of descent with 3 successive crosses of proved sires.
19 female lines of descent with 2 successive crosses of proved sires.

6-SIRE HERDS

CLARENCE SCHOONMAKER, GARDINER, N. Y., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2, 2A	20	(1)	E	(1)	King Korndyke Sadie Vale 11th 134640.
3, 3A	12	G	G	G	Dot Ormsby Lad 229310.
4, 4A	15	P	G	G	Sir Kilbrac Korndyke Piebe 288513.
5, 5A	37	F	F	F	Ormsby Sensation 49th 456462.
6, 6A	15	E	F	E	Dutchland Fayne Pietertje 565210.
8, 8A	11	E	P	U	Echohurst Inka Matador 591037.
7, 2, 2a	5	NP	NP	NP	
Total	115				
Number of daughters better than dams.		65	66	55	
		Percent	*Pounds*	*Pounds*	
Herd average of 126 cows		3.20	12,760	416	
Average of daughters by last sire.		3.30	13,522	447	

[1] Not given.

Conditions: 2 and 3 milkings, no correction.
8 female lines with 5 successive crosses of proved sires.
11 female lines with 4 successive crosses of proved sires.
31 female lines with 3 successive crosses of proved sires.
23 female lines with 2 successive crosses of proved sires.

AGRICULTURAL EXPERIMENT STATION, PURDUE UNIVERSITY, LAFAYETTE, IND., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
1	13	P	E	E	Gorgeous Boy 67767.
3	8	P	P	P	Estelle's Lad 75656.
5	11	U	P	P	Sayda's Purdue Heir 142282.
6	11	F	F	G	Fauvic's Juggler 205372.
7	7	E	P	F	Forward's Masterman Mogul 272867
8	9	F	E	E	Pride's Design Oxford 310968.
2, 4	5	NP	NP	NP	
Total	64				
Number of daughters better than dams.		29	36	38	
		Percent	*Pounds*	*Pounds*	
Herd average of 74 cows		5.42	8,102	440	
Average of daughters by last sire.		5.67	12,322	693	

Conditions: 2 and 3 milkings corrected to 3.
1 female line with 5 successive crosses of proved sires.
6 female lines with 4 successive crosses of proved sires.
6 female lines with 3 successive crosses of proved sires.
18 female lines with 2 successive crosses of proved sires.

MASSACHUSETTS STATE COLLEGE, AMHERST, MASS., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	6	U	P	P	Prince Pietertje Maid 42033.
3	9	F	G	G	Woodcrest Gordon Fayne 97208.
4	6	P	F	F	Mt. Hermon Sir Colantha Witkop 186740.
6	14	P	F	F	Mt. Hermon Sir Colantha Rupert 203655
7	6	E	G	E	Colantha Pietje Cornucopia Lad 427655.
9	7	E	U	F	Sir Star Inka Superior 460430.
5, 8, 10, 11, 12	11	NP	NP	NP	
Total	59				
Number of daughters better than dams.		33	30	28	
		Percent	*Pounds*	*Pounds*	
Herd average of 68 cows		3.39	13,835	473	
Average of daughters by last sire.		3.62	15,279	551	

Conditions: 2, 3, and 4 milkings corrected to 2.
12 female lines with 4 successive crosses of proved sires.
28 feamle lines with 3 successive crosses of proved sires.
33 female lines with 2 successive crosses of proved sires.

BRIGHAM FARM, ST. ALBANS, VT., JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
1	16	P	E	G	Owl Interest Victor 166581.
2	18	P	G	G	Sayda's King of Mendale 121724.
3	21	P	G	F	Owl's Royal Temesian 213175.
4	11	F	F	F	Spermfield Prince Interest 95697.
5	33	F	P	U	Lucile's Golden Owl 251626.
6	47	P	F	F	K. T. Lass Lad 291790.
Total	146				
Number of daughters better than dams.		62	78	71	
		Percent	*Pounds*	*Pounds*	
Herd average of 192 cows		5.34	7,684	406	
Average of daughters by last sire.		5.20	8,486	434	

Conditions: 2 milkings.
16 female lines with 4 successive crosses of proved sires.
37 female lines with 3 successive crosses of proved sires.
29 female lines with 2 successive crosses of proved sires.

C. A. MARK & SON, IOWA FALLS, IOWA, HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	5	E	E	E	Prince Segis Topsy 200462.
3	18	F	E	G	Roadside Uramagel DeKol 283483.
4	9	E	P	P	Sir Korndyke Ormsby Piebe Mercedes 3d 352280.
5	13	U	G	G	Sir Walker Segis Oak 4th 439966.
6	5	P	G	F	K. P. O. P. Tidy 24th 427496.
7	7	F	P	P	Sir Korndyke Ormsby Piebe Mercedes 25th 1568223.
Total	57				
Number of daughters better than dams.		29	36	32	
		Percent	*Pounds*	*Pounds*	
Herd average of 66 cows		3.52	17,886	628	
Average of daughters by last sire.		3.59	17,323	619	

Conditions: 2 milkings corrected to 3.
4 female lines of descent with 4 successive crosses of proved sires.
15 female lines of descent with 3 successive crosses of proved sires.
10 female lines of descent with 2 successive crosses of proved sires.

UNIVERSITY OF CALIFORNIA, DAVIS, CALIF., JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	11	E	E	E	Octavia's Rinda Lad 188257.
3	26	P	G	F	Pogis Torono Experimenter 177266.
3a	5	P	G	U	Pogis Torono Experimenter 177266.
4	19	F	F	G	Rutger's Farn Napoleon 189646.
5	6	F	G	E	Gravity's Exile of Lusscroft 162551.
6	8	G	F	G	Rinda Lad's St. Mawes Lad 201213.
3aa, 4a, 5a, 5aa, 7	8	NP	NP	NP	
Total	83				
Number of daughters better than dams.		43	49	51	
		Percent	*Pounds*	*Pounds*	
Herd average of 108 cows		5.59	7,554	417	
Average of daughters by last sire.		5.9	8,499	504	

Conditions: 2, 3, and 4 milkings, no correction.
4 female lines with 3 successive crosses of proved sires.
22 female lines with 2 successive crosses of proved sires.

6-SIRE HERDS—Continued

MAYWOOD FARMS, HEBRON, ILL., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
4	7		F	F	Maywood Duke Pontiac Hartog 317258.
5	5		P	P	Homestafa Ollie Shamrock 370453.
7	10		F	P	Kayewood Echo Sylvia Leed 402114.
9	9		F	F	Hollyhock Creation Segis Fobes 473008.
10	10		G	F	King Ormsby Field Piebe 569869.
11	6		G	G	Sir Fobes Dorlisha Mercedes 618156.
2, 3, 6, 8	6		NP	NP	
Total	53				
Number of daughters better than dams.			27	28	
			Pounds	*Pounds*	
Herd average of 79 cows			13,057	471	
Average of daughters by last sire.			14,358	521	

Conditions: 2 milkings.
1 female line with 4 successive crosses of proved sires.
8 female lines with 3 successive crosses of proved sires.
17 female lines with 2 successive crosses of proved sires.

MYRON STRATTON HOME, COLORADO SPRINGS, COLO., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
4	8	P	G	F	Sir Piebe Fayne Burke 264474.
5	38	F	E	E	Columbine Piebe Changeling 3rd 339930.
8	6	F	U	U	Institute Netherland Konigen 487266.
9	10	F	E	E	Stratton Sir Korndyke Rue 513426
10	9	F	P	P	Stratton Konigen Evermore 547258
11	6	P	G	F	Forest Glen Woodcraft Aaggie 593004.
2, 3, 6, 6A, 7, 7A, 7B, 8A, 12, 13, 14, 15, 16.	26	NP	NP	NP	
Total	103				
Number of daughters better than dams.		55	62	61	
		Percent	*Pounds*	*Pounds*	
Herd average of 122 cows		3.44	16,362	562	
Average of daughters by last sire.		3.44	18,863	643	

Conditions: 3 milkings.
13 female lines with 3 successive crosses of proved sires.
42 female lines with 2 successive crosses of proved sires.

UNIVERSITY OF MISSOURI, COLUMBIA, MO., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
3	6	G	P	P	Sir Kornd. Heng. DeKol 41266.
4	22	F	G	G	King Fayne Ormsby 237602.
5	5	G	P	F	Sir Fonda Hengerveld Ormsby 365514.
6	7	G	P	P	Grahamholm Colantha Sir Aaggie 457192.
7	5	P	F	U	Grahamholm Colantha Duke 455570.
9	8	G	G	G	Campus Aaggie Segis Sultan 586515
2, 8	8	NP	NP	NP	
Total	61				
Number of daughters better than dams.		32	30	31	
		Percent	*Pounds*	*Pounds*	
Herd average of 87 cows		3.38	18,675	630	
Average of daughters by last sire.		3.56	20,704	734	

Conditions: 3 milkings.
3 female lines of descent with 4 successive crosses of proved sires.
13 female lines of descent with 3 successive crosses of proved sires.
15 female lines of descent with 2 successive crosses of proved sires.

6-SIRE HERDS—Continued

OREGON STATE COLLEGE, CORVALLIS, OREG., JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
1	10	F	E	E	Golden Glow's Chief 61460.
2	8	G	G	G	Maple Park Chief 75537.
3	9	P	P	P	Glow St. Mawes 150362.
4	8	F	F	G	St. Mawes Grandson 189411.
6	10	E	P	P	The Maori's Hector 211805.
11	10	P	F	F	Sybil's Ashburn Prince 267890
5, 7, 8, 10	8	NP	NP	NP	
Total	63				
Number of daughters better than dams.		32	40	34	
		Percent	*Pounds*	*Pounds*	
Herd average of 72 cows		5.40	8,071	439	
Average of daughters by last sire.		5.38	8,304	484	

Conditions: 2 and 3 milkings corrected to 2 milkings.
4 female lines with 7 successive crosses of proved sires.
3 female lines with 6 successive crosses of proved sires.
7 female lines with 5 successive crosses of proved sires.
23 female lines with 4 successive crosses of proved sires.
20 female lines with 3 successive crosses of proved sires.
12 female lines with 2 successive crosses of proved sires.

5-SIRE HERDS

AGRICULTURAL EXPERIMENT STATION, PURDUE UNIVERSITY, LAFAYETTE, IND., HOLSTEINS

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
5	5	F	E	E	King Segis Hengerveld 5th 126572.
7	8	F	P	P	King Segis Commodore Perry 201857.
8	9	U	E	E	Paul Fobes Butter King 251010.
9	11	E	E	E	King Pietertje Ormsby Piebe 33d 355214.
12	6	E	G	E	King Triune Rose Wayne Betta 588922.
1, 2, 3, 4, 6, 10, 11	15	NP	NP	NP	
Total	54				
Number of daughters better than dams.		39	36	39	
		Percent	*Pounds*	*Pounds*	
Herd average of 59 cows		3.26	16,925	556	
Average of daughters by last sire.		3.65	19,574	721	

Conditions: 2 and 3 milkings corrected to 3.
3 female lines with 5 successive crosses of proved sires
4 female lines with 4 successive crosses of proved sires
7 female lines with 3 successive crosses of proved sires
6 female lines with 2 successive crosses of proved sires.

FAIRVIEW FARM, CORNWALL, PA., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	10	G	E	E	Tops of Gold of Stockdale 52967.
4	30	G	E	E	Flasham Superior 70439.
5	19	E	F	F	Me Plus Ultra of Edgemere 64956.
8	10	P	G	G	Fairview Athletic Prospector 151633.
10	9	F	F	F	Tampa's Ultimus of Fairview 187074.
3, 7, 9	8	NP	NP	NP	
Total	86				
Number of daughters better than dams.		59	55	63	
		Percent	*Pounds*	*Pounds*	
Herd average of 116 cows		4.86	9,130	440	
Average of daughters by last sire.		5.03	9,327	465	

Conditions: 2 and 3 milkings, not corrected, Dairy Herd Improvement Association, 305 days.
4 female lines of descent with 4 successive crosses of proved sires.
11 female lines of descent with 3 successive crosses of proved sires.
38 female lines of descent with 2 successive crosses of proved sires.

5-SIRE HERDS—Continued

OTTO CIVIL, MIDLOTHIAN, VA., GUERNSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
2	22	F	F	F	High Point Glory Boy 42425.
3	21	F	U	F	Nellie's April Secret 78131.
4	16	G	P	F	Handsome Golden Charlie 75362.
5	6	G	E	E	Saugerties Steadfast's Cavalier 112697.
7	8	P	G	G	Winston Farms Golden 124737.
6, 8	8	NP	NP	NP	
Total	81				
Number of daughters better than dams.		50	47	46	
		Percent	*Pounds*	*Pounds*	
Herd average of 107 cows		4.94	11,214	554	
Average of daughters by last sire.		4.86	11,870	574	

Conditions: 2 and 3 milkings corrected to 3.
2 female lines with 4 successive crosses of proved sires.
18 female lines with 3 successive crosses of proved sires.
51 female lines with 2 successive crosses of proved sires.

MONTANA STATE COLLEGE, BOZEMAN, MONT., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
5	9	P	F	U	Montana Torono 113658.
6	6	G	G	G	Sophie 19 Tormentor 29th 163910.
7	5	P	E	G	Oregon St. Mawes Doctor 169221.
9	13	F	F	F	Boise Queen's Silver Lad 231043.
10	11	G	G	E	Helen's St. Mawes Hopemeadow 292715.
2, 3, 4, 11	6	NP	NP	NP	
Total	50				
Number of daughters better than dams.		27	29	32	
		Percent	*Pounds*	*Pounds*	
Herd average of 55 cows		5.49	8,268	454	
Average of daughters by last sire.		5.86	9,511	555	

Conditions: 2 milkings.
5 female lines of descent with 5 successive crosses of proved sires.
12 female lines of descent with 4 successive crosses of proved sires.
13 female lines of descent with 3 successive crosses of proved sires.
13 female lines of descent with 2 successive crosses of proved sires.

UTAH STATE COLLEGE, LOGAN, UTAH, HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
5	6	G	E	E	Pontiac Pegassus 62878.
9	10	E	P	F	Edenwold Colantha Pietertje 151007
10	5	P	E	G	Hollywood Abbekerk Segis 388432.
12	6	P	F	P	Galiah of Hollywood 2d 411759.
13	7	F	F	F	Sir Inka May 23rd 575503.
2, 3, 4, 6, 7, 8, 11	11	NP	NP	NP	
Total	45				
Number of daughters better than dams.		25	24	26	
		Percent	*Pounds*	*Pounds*	
Herd average of 54 cows		3.24	19,277	629	
Average of daughters by last sire.		3.23	20,257	669	

Conditions: 2 and 3 milkings corrected to 3-milkings 365 days.
2 female lines with 5 successive crosses of proved sires.
2 female lines with 4 successive crosses of proved sires.
2 female lines with 3 successive crosses of proved sires.
8 female lines with 2 successive crosses of proved sires.

5-SIRE HERDS—Continued

TORRANCE STATE HOSPITAL, TORRANCE, PA., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
3	9	P	E	G	King Segis Fayne The Great 265538.
4	32	P	E	E	Bell Farm Retainer 355611.
5	9	F	G	G	Bell Farm Triumph 450762.
6	10	G	F	E	Dagan Ormsby Getati 477272.
7	10	G	G	E	Sir Pansy Piebe 517620.
2	0	NP	NP	NP	
Total	70				
Number of daughters better than dams.		27	52	54	
		Percent	*Pounds*	*Pounds*	
Herd average of 101 cows		3.29	12,243	391	
Average of daughters by last sire.		3.28	14,087	464	

Conditions: 2 milkings, Dairy Herd Improvement Association.
7 female lines with 4 successive crosses of proved sires.
20 female lines with 3 successive crosses of proved sires.
19 female lines with 2 successive crosses of proved sires.

SCHAAF DAIRY, COLUMBUS, OHIO, HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
	5	F	P	P	Clyde Paul DeKol 6th 68020.
	17	G	G	G	Lothian Hengerveld DeKol Korndyke 97920.
	32	U	U	U	Meadow Holm Sir Edna Hartog 179849.
	15	G	U	G	Prince Pontiac Hartog of Bexley 298042.
	19	P	F	F	Dirmere Sir Ollie Polkadot Pontiac 521787.
Total	88				
Number of daughters better than dams.		55	42	48	
		Percent	*Pounds*	*Pounds*	
Herd average of 103 cows		3.43	13,531	457	
Average of daughters by last sire.		3.45	14,337	492	

Conditions: 2 milkings corrected to 3.
1 female line with 6 successive crosses of proved sires.
2 female lines with 5 successive crosses of proved sires.
9 female lines with 4 successive crosses of proved sires.
15 female lines with 3 successive crosses of proved sires.
26 female lines with 2 successive crosses of proved sires.

D. G. MILLER & SONS FARM, EATON RAPIDS, MICH., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
	10	F	F	F	Island City Glista Pride 406025.
2	5	P	G	G	Peacedale Ormsby Segis 377899.
3	28	P	E	E	Blythefield King Wayne Cornucopia 344001.
4	31	P	E	E	King Pontiac Segis Fobes 538318.
5	11	P	E	G	Blythefield Model King 581693.
Total	85				
Number of daughters better than dams.		35	65	62	
		Percent	*Pounds*	*Pounds*	
Herd average of 115 cows		3.56	11,339	400	
Average of daughters by last sire.		3.48	13,397	467	

Conditions; 2 milkings.
1 female line of descent with 4 successive crosses of proved sires.
17 female lines of descent with 3 successive crosses of proved sires.
21 female lines of descent with 2 successive crosses of proved sires.

5-SIRE HERDS—Continued

H. L. ALLEN & CO., DUVALL, WASH., JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
2	6	E	G	E	Gertie's Stope Pogis 31st 87943.
3	9	F	P	P	Violet's Laddie 106919.
4	29	E	G	E	Susy's St. Mawes 2nd 155866
9	11	E	F	E	Rinda Lad of Washington 229614.
10	20	F	P	U	St. Mawes Prince Charming 266692.
5, 6, 7, 8, 11, 12, 15	14	NP	NP	NP	
Total	89				
Number of daughters better than dams.		65	44	55	
		Percent	*Pounds*	*Pounds*	
Herd average of 114 cows		5.50	8,316	458	
Average of daughters by last sire.		5.70	8,169	466	

Conditions; 2 milkings, Dairy Herd Improvement Association.
1 female line with 6 successive crosses of proved sires.
1 female line with 5 successive crosses of proved sires.
9 female lines with 4 successive crosses of proved sires
23 female lines with 3 successive crosses of proved sires.
25 female lines with 2 successive crosses of proved sires.

SOUTH CAROLINA STATE HOSPITAL, COLUMBIA, S. C., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
2		P	E	G	Veeman Fobes Pietje Pontiac 338940
6		F	P	P	Sarcastic Hero Lad 310535.
10		U	F	U	U. S. S. H. General Piebe Lad 512146.
11		F	G	G	King Ormsby Segis Hunter 494955.
14		U	F	F	Winterthur Boast Herald 496287.
3, 4, 5, 7, 8, 9, 12, 13		NP	NP	NP	
Total					
Number of daughters better than dams.		47	52	52	
		Percent	*Pounds*	*Pounds*	
Herd average of 125 cows		3.37	18,873	634	
Average of daughters by last sire.		3.29	20,294	666	

Conditions; Advanced registry, 2 and 3 milkings corrected to 3
1 female line with 4 successive crosses of proved sires
6 female lines with 3 successive crosses of proved sires.
27 female lines with 2 successive crosses of proved sires.

SOUTH DAKOTA STATE COLLEGE OF AGRICULTURE, BROOKINGS, S. DAK., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
2	8	P	F	U	Sir Cornucopia Prince 48663.
3	7	P	P	P	King Colantha Clothilde 2nd 83763.
5	6	G	F	F	Sir Korndyke Bess Piebe 159537.
10	17	G	G	E	Sir Auggie Colantha Korndyke 260390.
11	8	E	U	G	Redfield Sir Johanna Piebe 551817.
1, 4, 6, 7, 8, 9, 12	17	NP	NP	NP	
Total	63				
Number of daughters better than dams.		40	25	28	
		Percent	*Pounds*	*Pounds*	
Herd average of 77 cows		3.40	13,336	455	
Average of daughters by last sire.		3.78	13,200	502	

Conditions; 2 and 4 milkings, no correction.
2 female lines of descent with 4 successive crosses of proved sires.
7 female lines of descent with 3 successive crosses of proved sires.
19 female lines of descent with 2 successive crosses of proved sires.

5-SIRE HERDS—Continued

LARRO RESEARCH FARM, BEDFORD, MICH., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	18	U	P	P	King Netherland Rue Walker 335813.
5	12	F	E	E	Velvet Segis Ormsby Piebe 433546.
6	11	F	G	G	Laro Segis Lillith Champion 519369.
7	6	P	E	G	Laro King Gelsche Korndyke 462473.
9	10	G	E	E	Ormsby Sensation 4136 429976.
3, 4, 8, 10, 11	12	NP	NP	NP	
Total	69				
Number of daughters better than dams.		45	41	44	
		Percent	*Pounds*	*Pounds*	
Herd average of 106 cows		3.29	12,247	403	
Average of daughters by last sire.		3.39	14,020	478	

Conditions: 2 milkings, Dairy Herd Improvement Association.
5 female lines with 3 successive crosses of proved sires.
15 female lines with 2 successive crosses of proved sires.

WESTERN PENITENTIARY, BELLEFONTE, PA., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2 by 7½	41	P	E	G	Nittanyreale Aaggie Foyalsack 486534.
4	11	U	E	E	Fayne Sack Sir Aaggie Pet 364374.
5	15	F	G	E	Korndyke Doxey Clothilda 455345.
6	16	U	E	E	King Champion Janneck 18th 460879.
8	6	P	E	E	Bouheur Wayne 3rd 524680.
3, 9, 10	11	NP	NP	NP	
Total	100				
Number of daughters better than dams.		45	73	71	
		Percent	*Pounds*	*Pounds*	
Herd average of 147 cows		3.42	14,661	500	
Average of daughters by last sire.		3.21	19,573	628	

Conditions: 2 and 3 milkings, no correction.
1 female line with 3 successive crosses of proved sires.
48 female lines with 2 successive crosses of proved sires

R. L. SHUFORD, NEWTON, N. C., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	5	P	F	P	Biltmore's Torment 60761.
4	10	F	P	P	Eminent the 10th 75753.
6	5	U	G	G	Eminent's Flying Fox 75266.
8, 9	25	F	G	G	Oakwood D's Fox 126834.
13	9	E	F	E	Sybil's Jubilant Gamboge 226488.
1, 3, 5, 7, 10, 11, 12	13	NP	NP	NP	
Total	67				
Number of daughters better than dams.		39	33	35	
		Percent	*Pounds*	*Pounds*	
Herd average of 97 cows		5.41	11,240	601	
Average of daughters by last sire.		5.75	13,088	751	

Conditions: 3 milkings.
7 female lines of descent with 3 successive crosses of proved sires.
19 female lines of descent with 2 successive crosses of proved sires.

UNIVERSITY OF NEBRASKA EXPERIMENT SUBSTATION, NORTH PLATTE, NEBR., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
8	5	F	G	E	Varsity Derby Matador 234809.
9	16	U	F	F	Varsity Piebo La Vertex 302952.
15	9	G	P	F	Count Ormsby Segis Pontiac 338994.
19	10	G	U	F	N. P. Hengerveld Topsy Cou[illegible] 479846.
21	10	P	P	P	Sir Triune Pansy 24th 558807.
2, 4, 6, 12, 17, 20	10	NP	NP	NP	
Total	60				
Number of daughters better than dams		31	27	26	
		Percent	Pounds	Pounds	
Herd average of 75 cows		3.66	18,641	679	
Average of daughters by last sire.		3.51	17,251	603	

Conditions: 4 milkings, advanced register corrected to 3.
11 female lines of descent with 3 successive crosses of proved sires.
22 female lines of descent with 2 successive crosses of proved sires.

HENRY WATERS, GREENWOOD, TENN., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
7	6	F	F	G	Fox's Gray Owl 117253.
12	5	U	E	E	Owl Interest Rival 184742.
13	7	P	E	F	Faun's You'll Do 173021.
15	12	U	P	U	Fairy Boy's Raleigh Boy 131418.
18	12	G	F	G	Imported Samuel 304980.
2, 3, 4, 5, 6, 8, 9, 10, 11, 14, 16, 17	17	NP	NP	NP	
Total	59				
Number of daughters better than dams.		33	34	37	
		Percent	Pounds	Pounds	
Herd average of 77 cows		5.54	9,708	541	
Average of daughters by last sire.		5.78	10,653	611	

Conditions: Register of merit sires 7, 12, and 13; 2 and 3 milkings; 15 and 18, 3 milkings.
2 female lines with 3 successive crosses of proved sires.
8 female lines with 2 successive crosses of proved sires.

VINELAND TRAINING SCHOOL, VINELAND, N. J., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2A	5	G	F	F	Paul Pontiac Canary Nig De Kol 30762[illegible]
3A-2B-11A	14	F	F	F	Calamo Waldorf 413040.
4A-12A	10	F	E	E	Readson Vale Sylvia Fayne 412727.
5A-15A	19	F	E	E	Vineland Springwell Calamo 526381.
7A-16A	11	U	P	P	Forsgate Model Perfection 576514.
6A, 8A, 13A, 14A	9	NP	NP	NP	
Total	68				
Number of daughters better than dams.		40	40	40	
		Percent	Pounds	Pounds	
Herd average of 90 cows		3.27	13,748	448	
Average of daughters by last sire.		3.35	12,423	417	

Conditions: Number of milkings not given.
9 female lines with 3 successive crosses of proved sires.
19 female lines with 2 successive crosses of proved sires.

4-SIRE HERDS

STATE FARMS, ARCHER, WYO., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	6	P	E	E	Sir Arthur Paul Veeman 238796.
4	6	F	E	E	Wyoming Pontiac Ormsby 276300.
10	13	F	G	G	Brands Matador Watson 584791.
11	8	E	P	F	Pride Friend Ormsby Homesteader 571261.
6, 8, 9, 12	9	NP	NP	NP	
Total	42				
Number of daughters better than dams.		28	29	31	
		Percent	*Pounds*	*Pounds*	
Herd average of 62 cows		3.40	16,357	553	
Average of daughters by last sire.		3.69	16,484	606	

Conditions: 2 milkings corrected to 3 (factor 1.45) with adjustment for 305-day basis.
1 female line of descent with 4 successive crosses with proved sires.
5 female lines of descent with 3 successive crosses with proved sires.
13 female lines of descent with 2 successive crosses with proved sires

B. FRANK COOPER, HANNIBAL, MO., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
3	7	G	E	E	Western King's Fox 131640.
4	18	P	G	F	Vixen's Oxford Bean 131638.
5	[1] 19	F	G	G	Gapon's Countess Lad 159969.
6	11	P	F	F	Bonner Jap Baron 169139.
2, 7	5	NP	NP	NP	
Total	60				
Number of daughters better than dams.		31	36	35	
		Percent	*Pounds*	*Pounds*	
Herd average of 77 cows		5.48	8,648	471	
Average of daughters by last sire.		5.44	9,501	514	

[1] 7 daughters sold because of low production.
Conditions: 2 milkings.
2 female lines with 4 successive crosses of proved sires.
12 female lines with 3 successive crosses of proved sires.
13 female lines with 2 successive crosses of proved sires.

LOUISIANA STATE UNIVERSITY, BATON ROUGE, LA., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
3	6	F	P	P	Iowana Al
6	5	F	G	G	Oakdale Sp
10	33	G	E	E	Oakdale Jo
13	39	F	G	E	Pabst Prill
2, 4, 5, 7, 8, 9, 12, 15	12	NP	NP	NP	
Total	95				
Number of daughters better than dams.		60	64	71	
		Percent	*Pounds*	*Pounds*	
Herd average of 116 cows		3.46	13,986	485	
Average of daughters by last sire.		3.46	15,056	527	

Conditions: 3 milkings.
4 female lines with 4 successive crosses of proved sires.
9 female lines with 3 successive crosses of proved sires.
26 female lines with 2 successive crosses of proved sires.

4-SIRE HERDS—Continued

LONG LANE FARM, MIDDLETOWN. CONN., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
3	7	F	E	E	Mount Herman Sir Gladice 357166.
4, 6	23	P	E	G	Mount Herman Sir Kelvyn 438012.
5	9	G	F	G	Osborndale North Star Champion 493526
7	5	G	E	E	Winterthur Dad Boast Leo 636559.
2	1	NP	NP	NP	
Total	45				
Number of daughters better than dams.		21	33	28	
		Percent	*Pounds*	*Pounds*	
Herd average of 60 cows		3.34	14,357	481	
Average of daughters by last sire.		3.38	18,200	609	

Conditions: 2 and 3 milkings, no correction
11 female lines of descent with 3 successive crosses of proved sires
17 female lines of descent with 2 successive crosses of proved sires

WESTERN WASHINGTON EXPERIMENT STATION, PUYALLUP, WASH., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
	5	F	G	G	Segis Pontiac DeKol Burke 2d 152561.
	7	P	G	G	Piebe Hero 311689.
	21	F	G	G	Steilacoom Prilly Ormsby Sylvia 407735.
	7	F	F	G	Chinook Homestead Cal 561262
	2	NP	NP	NP	
Total.	42				
Number of daughters better than dams.		18	21	26	
		Percent	*Pounds*	*Pounds*	
Herd average of 59 cows		3.24	12,490	404	
Average of daughters by last sire.		3.49	13,349	466	

Conditions: 2 and 3 milkings, corrected to 2.
6 female lines with 3 successive crosses of proved sires.
9 female lines with 2 successive crosses of proved sires.

H. T. PATRICK, RUSTBURG, VA., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	8	E	E	E	Genteel John 191042.
3	14	G	G	E	Pogis Orange Prince 238748.
4	7	F	F	F	Sybil's Gypsy King 3d 224962.
5	11	G	E	E	Pansy's Eminent Nobleman 247728.
1	2	NP	NP	NP	
Total	42				
Number of daughters better than dams.		30	30	32	
		Percent	*Pounds*	*Pounds*	
Herd average of 76 cows		5.03	8,229	414	
Average of daughters by last sire.		5.34	8,889	470	

Conditions: 2 milkings, Dairy Herd Improvement Association.
2 female lines of descent with 3 successive crosses of proved sires.
22 female lines of descent with 2 successive crosses of proved sires.

4-SIRE HERDS—Continued

W. O. WILSON, HILLANDALE FARM, PURCELLVILLE, VA., GUERNSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	5	E	G	E	Park's Gypsy Lad 53768.
3	7	F	F	F	Ophir's Ultra Sun 121177.
4	28	F	F	F	Brownlie Monarch 139792.
5	5	G	E	E	Majesty of Lombardy 161659.
Total	45				
Number of daughters better than dams.		29	33	30	
		Percent	*Pounds*	*Pounds*	
Herd average of 73 cows		4.92	9,423	463	
Average of daughters by last sire.		5.08	10,881	552	

Conditions: 2 milkings.
2 females lines with 3 successive crosses of proved sires.
13 female lines with 2 successive crosses of proved sires.

J. W. LOVING, PUEBLO, COLO., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	10	E	U	G	College Regulator 79726.
3	9	P	P	P	Mixter Warcloud 100133.
5	10	P	E	E	St. Craix Warren 74815.
6	10	F	E	E	Charm's Valor 183830.
1, 4, 7, 8	6	NP	NP	NP	
Total	45				
Number of daughters better than dams.		24	25	26	
		Percent	*Pounds*	*Pounds*	
Herd average of 67 cows		4.78	11,259	526	
Average of daughters by last sire.		4.80	13,405	619	

Conditions: 2 and 3 milkings corrected to 3.
2 female lines of descent with 3 successive crosses of proved sires.
21 female lines of descent with 2 successive crosses of proved sires.

MASSACHUSETTS STATE COLLEGE, AMHERST, MASS., AYRSHIRE

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	5	F	E	E	Alta Crest King of Beauty 2d 15033.
4	12	G	P	P	Alta Crest Trailmaker 21765.
6	8	U	F	F	Alta Crest Ringleader 29112.
7	8	U	F	F	Alta Crest Pathfinder 33325.
3, 8	2	NP	NP	NP	
Total	35				
Number of daughters better than dams.		21	17	17	
		Percent	*Pounds*	*Pounds*	
Herd average of 53 cows		4.11	9,927	407	
Average of daughters by last sire.		4.06	11,044	450	

Conditions: 3 milkings.
1 female line with 1 successive cross of proved sires.
5 female lines with 3 successive crosses of proved sires.
10 female lines with 2 successive crosses of proved sires.

4-SIRE HERDS—Continued

FABIUS FARMS (ARTHUR L. JONES), THREE RIVERS, MICH., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
1	16	G	U	F	Pabst Creator A
2	17	P	G	F	Pabst Prilly Cr
3	16	G	F	G	Count Veeman
4	7	F	P	F	King Ormsby I
Total	56				
Number of daughters better than dams.		41	28	32	
		Percent	*Pounds*	*Pounds*	
Herd average of 83 cows		3.35	12,871	426	
Average of daughters by last sire.		3.36	13,447	450	

Conditions: 3 milkings.
3 female lines of descent with 3 successive crosses of proved sires.
19 female lines of descent with 2 successive crosses of proved sires.

BLOSSOM HILL FARM, LEBANON, N. J., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
4a, 13a, 4b	12	P	F	U	King Pontiac Model Champion 301697
5a, 16a, 6b	7	G	U	F	Blossom Hill King Echo 486337.
8a, 14a, 5b, and 8	46	P	F	F	King Echo Pietje 346895.
10a, 15a, 3b, and 9b	46	F	F	F	Triune King Valentine 488531.
2a, 3a, 6a, 7, 9, 11a, 12, 13, 14, 15	13	NP	NP	NP	
Total	124				
Number of daughters better than dams.		67	74	75	
		Percent	*Pounds*	*Pounds*	
Herd average of 156 cows		3.31	16,129	532	
Average of daughters by last sire.		3.31	16,422	544	

Conditions: 2 milkings, corrected to 3.
7 female lines with 3 successive crosses of proved sires
38 female lines with 2 successive crosses of proved sires

POLK STATE HOSPITAL, POLK, PA., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	5	E	P	E	King Champion Jannet 72882.
5	30	U	P	P	Brookside Waldorf Prince Abberkirk 339372.
6	62	F	U	F	Pabst Creator Amos 457546.
8	67	G	F	G	Sir Inka May 21. 561789.
3, 4, 7	5	NP	NP	NP	
Total	169				
Number of daughters better than dams.		113	78	90	
		Percent	*Pounds*	*Pounds*	
Herd average of 249 cows		3.51	13,464	472	
Average of daughters by last sire.		3.66	14,071	513	

Conditions: 2 milkings, Dairy Herd Improvement Association.
34 female lines with 3 successive crosses of proved sires.
107 female lines with 2 successive crosses of proved sires.

IONIA STATE HOSPITAL, IONIA, MICH., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
1	11	F	E	E	Newberry Belldora Aggie 404293.
3	11	F	U	F	Pontiac College Paul 507031.
4	15	F	F	G	Traverse Echo Model Marathon 504402
5	5	G	G	G	Reformatory King Aggie Ormsby 568009.
2	4	NP	NP	NP	
Total	46				
Number of daughters better than dams.		29	27	31	
		Percent	*Pounds*	*Pounds*	
Herd average of 67 cows		3.39	16,885	570	
Average of daughters by last sire.		3.43	18,372	627	

Conditions: 3 milkings.
2 female lines of descent with 3 successive crosses of proved sires.
12 female lines of descent with 2 successive crosses of proved sires.

W. J. SMITH, SHEDS, N. Y., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
4	14	G	G	E	Browleigh Segis Spoffard 384148.
5	6	F	P	P	Premier Colantha Homestead Boy 516226.
6	7	F	E	E	King Pontiac Walker Lyons 456304.
7	11	G	E	G	Trestleview Pontiac Echo 552916
2, 3, 8	5	NP	NP	NP	
Total	43				
Number of daughters better than dams.		29	27	29	
		Percent	*Pounds*	*Pounds*	
Herd average of 54 cows		3.45	11,362	393	
Average of daughters by last sire.		3.63	11,701	128	

Conditions: 2 milkings.
2 female lines of descent with 3 successive crosses of proved sires.
16 female lines of descent with 2 successive crosses of proved sires.

JOHN S. AMES, LANGWATER FARM, NORTH EASTON, MASS., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	22	G	F	G	Langwater Steadfast 31672.
3	18	U	F	F	Langwater Valiant 51868.
4	8	G	P	P	Langwater Sheik 77112.
5	17	F	F	F	Langwater Pharaoh 98719.
Total	65				
Number of daughters better than dams.		40	36	36	
		Percent	*Pounds*	*Pounds*	
Herd average of 106 cows		5.02	10,576	529	
Average of daughters by last sire.		5.02	10,913	548	

Conditions: 3 milkings advanced register corrected to 2.
2 female lines with 3 successive crosses of proved sires.
15 female lines with 2 sucessive crosses of proved sires.

E. PARMALEE PRENTICE, MOUNT HOPE FARM, WILLIAMSTOWN, MASS., GUERNSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
4	7	P	F	P	Mount Hope Pride 65425
5	9	P	P	P	Murne Cowan's Governor of Mount Hope 52602.
6	5	P	E	E	Itchen King 49803.
7	12	P	E	E	Noble Regent of Allenwood 44384.
2, 3, 8	6	NP	NP	NP	
Total	39				
Number of daughters better than dams.		13	26	25	
		Percent	*Pounds*	*Pounds*	
Herd average of 54 cows		4.96	8,881	436	
Average of daughters by last sire.		4.83	10,738	516	

Conditions: 3 milkings corrected to 2.
1 female line with 3 successive crosses of proved sires.
10 female lines with 2 successive crosses of proved sires.

SAUNDERS & MYERS, LEESBURG, VA., GUERNSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
1	16	F	F	F	Marvern's May Rose King 23301.
4	24	F	F	F	Prides Raides of Rosemont 68317.
5	23	G	E	E	Caumsett Polly's Foremost 106864.
6	6	G	G	E	Foremost King of Lombardy 207808.
2, 3	3	NP	NP	NP	
Total	72				
Number of daughters better than dams.		46	41	45	
		Percent	*Pounds*	*Pounds*	
Herd average of 131 cows		4.77	10,239	487	
Average of daughters by last sire.		4.90	10,607	511	

Conditions: 2 milkings corrected to 3.
1 female line of descent with 3 successive crosses of proved sires.
17 female lines of descent with 2 successive crosses of proved sires.

J. A. PHILLIPS, MIDDLEBURY, VT., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
2	5	P	F	F	King Pontiac Alban Hengerveld 244229.
3	11	E	P	U	Duke Pontiac H. K. 310211.
4	6	F	F	F	Sir Segis DeKol Alartra 222171.
5	15	U	G	G	King Sylvia Lyons Pontiac 499878.
1, 6	2	NP	NP	NP	
Total	39				
Number of daughters better than dams.		22	20	22	
		Percent	*Pounds*	*Pounds*	
Herd average of 44 cows		3.53	9,802	343	
Average of daughters by last sire.		3.48	10,708	372	

Conditions: 2 milkings, 305 days, Dairy Herd Improvement Associatio
1 female line of descent with 3 successive crosses of proved sires.
17 female lines of descent with 2 successive crosses of proved sires.

4-SIRE HERDS

UNIVERSITY OF ARIZONA, TUCSON, ARIZ., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
6	6	E	P	F	Idaho Matador Conqueror 384967.
7	11	E	P	F	Gila King Ormsby Fytje Mercedes. 440883.
8	7	F	P	U	U. of A. Theresa Bell Matador Ormsby 454800.
9	6	F	G	G	Maricopa Marathon Eden Duke 556456.
2, 3, 4, 5	8	NP	NP	NP	
Total	38				
Number of daughters better than dams.		29	17	17	
		Percent	Pounds	Pounds	
Herd average of 49 cows		3.34	16,863	562	
Average of daughters by last sire		3.55	18,291	648	

Conditions: 2, 3, and 4 milkings, corrected to 3.
1 female line wth 3 successive crosses of proved sires.
5 female lines wth 2 successive crosses of proved sires.

L. J. TENCKINCK, TWIN FALLS, IDAHO, HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
3	6	F	E	E	Lava Rock Sarcastic Alcartra 412711.
5	5	P	G	G	Gem State Colantha Fobes 506083.
6	6	E	E	E	Colantha McKinley Fobes 565293.
7	6	G	G	E	Halton's Piebe Colantha Eolia 558646.
2, 4, 10	5	NP	NP	NP	
Total	28				
Number of daughters better than dams.		16	19	20	
		Percent	Pounds	Pounds	
Herd average of 39 cows		3.58	16,728	604	
Average of daughters by last sire.		3.73	18,405	684	

Conditions: 2 milkings corrected to 3.
5 female lines of descent with 2 successive crosses of proved sires.

KNAPP SCHOOL OF COUNTRY LIFE, NASHVILLE, TENN., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
8	9	G	G	E	College King Cornucopia De Kol 349914.
9	5	F	P	P	Knapp Butterboy Segis De Kol 527855.
10	8	G	F	G	Knapp De Kol Ormsby Abbekerk 503070.
12	6	G	G	E	Breezy Lane Countess Ormsby 624195.
2, 3, 4, 5, 6, 7, 11	12	NP	NP	NP	
Total	40				
Number of daughters better than dams.		29	17	22	
		Percent	Pounds	Pounds	
Herd average of 52 cows		3.38	16,677	565	
Average of daughters by last sire.		3.54	18,639	659	

Conditions: 3 milkings.
6 female lines with 2 successive crosses of proved sires.

NORTH DAKOTA PENITENTIARY, BISMARCK, N. DAK., HOLSTEINS

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	5	E	P	P	Kota Governor Sunnyside Pontiac 465723.
3	7	G	G	E	Dean Ormsby Mercedes 21st 533162.
4	6	U	U	F	Sir Johanna Ormsby Marlono 255217.
5	9	E	F	E	Bacon Colantha Zubrod 330742.
1, 6	5	NP	NP	NP	
Total	32				
Number of daughters better than dams.		23	14	20	
		Percent	*Pounds*	*Pounds*	
Herd average of 75 cows		3.37	14,583	488	
Average daughters by last sire.		3.62	15,350	555	

Conditions: 3 milkings, Dairy Herd Improvement Association.
7 female lines with 2 successive crosses of proved sires.

SYCAMORE FARMS, DOUGLASVILLE, PA., AYRSHIRE

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
3	5	G	P	F	Shew Altin Maines Ideal 18078.
5	9	E	F	G	Glen Fairse Governor 28478.
10	11	E	G	G	Penshurst Advancer 35022.
11	10	E	P	F	Penshurst Lindy 35053.
2, 4, 6, 7, 8, 9	13	NP	NP	NP	
Total	48				
Number of daughters better than dams.		41	24	28	
		Percent	*Pounds*	*Pounds*	
Herd average of 84 cows		4.19	11,107	465	
Average of daughters by last sire.		4.59	10,731	491	

Conditions: 2 milkings.
5 female lines with 2 successive crosses of proved sires.

NEBRASKA SCHOOL OF AGRICULTURE, CURTIS, NEBR., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
4	9	G	E	E	King Gerben Lyons 196903.
7	10	G	F	F	Varsity Piebe Aristocrat 362572.
9	7	G	P	P	U. Nebraska King La Vim 458458.
15	6	P	E	E	N. P. Clothilde Topsy King Ormsby 652463.
3, 5, 6, 8, 10, 11, 14, 16, 17, 18	22	NP	NP	NP	
Total	54				
Number of daughters better than dams.		28	32	32	
		Percent	*Pounds*	*Pounds*	
Herd average of 63 cows		3.67	18,146	664	
Average of daughters by last sire.		3.66	21,558	787	

Conditions: 2, 3, and 4 milkings corrected to 3.
1 female line with 4 successive crosses of proved sires.
2 female lines with 3 successive crosses of proved sires.
17 females lines with 2 successive crosses of proved sires.

4-SIRE HERDS—Continued

UTAH STATE AGRICULTURAL COLLEGE, LOGAN, UTAH, JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
4	8	G	P	P	Marguerite's Noble Chief 100838.
8	11	P	E	G	Nan's Golden Raleigh 197737.
10	6	G	G	E	St. Mawes Oxford Reuben 259231.
11	5	P	E	E	Helen's Oregon St. Mawes 262455.
2, 3, 5, 6, 7, 9, 12	16	NP	NP	NP	
Total	46				
Number of daughters better than dams.		23	27	29	
		Percent	*Pounds*	*Pounds*	
Herd average of 56 cows		5.36	8,247	438	
Average of daughters by last sire.		5.20	10,018	518	

Conditions: 2 milkings, 305 days corrected to 365 days.
5 female lines with 2 successive crosses of proved sires.

C. S. M'CALL, BENNETTSVILLE, S. C., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
		G	G	G	Beauty's Raider of Waddington 41801.
		U	F	F	Fern's Raider of Appin 64700.
		E	F	F	Upland's General 79094.
12		G	P	P	Foremost's Golden Boy 103080.
2, 4, 7, 8, 10, 11		NP	NP	NP	
Total	47				
Number of daughters better than dams.		32	20	20	
		Percent	*Pounds*	*Pounds*	
Herd average of 73 cows		5.15	11,251	576	
Average of daughters by last sire.		5.49	10,002	539	

Conditions: 3 milkings.
3 female lines with 3 successive crosses of proved sires.
8 female lines with 2 successive crosses of proved sires.

3-SIRE HERDS

JAMES McGEE, FREDERICKSBURG, VA., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	11	G	G	E	Majesty's Admiral 172934.
4	14	F	G	G	Tripple Hood Farm Torono 270579.
5	17	G	E	E	Sophie's Torono King George 277122.
1, 3	2	NP	NP	NP	
Total	44				
Number of daughters better than dams.		27	34	37	
		Percent	*Pounds*	*Pounds*	
Herd average of 60 cows		4.92	8,276	403	
Average of daughters by last sire.		5.21	9,541	495	

Conditions: 2 milkings.
4 female lines with 3 successive crosses of proved sires.
12 female lines with 2 successive crosses of proved sires.

HARRY ILIFF, INDEPENDENCE, OREG., JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires			Name of sire
		Percentage of butterfat	Production of—		
			Milk	Butterfat	
1	5	E	G	E	St. Mawes Lad 130501.
4	8	E	P	P	The Maori 172121.
5	8	G	F	F	Lilac's St. Mawes 266052.
2, 3, 6, 7, 8	8	NP	NP	NP	
Total	29				
Number of daughters better than dams.		24	13	17	
		Percent	*Pounds*	*Pounds*	
Herd average of 34 cows		6. 32	14, 415	919	
Average of daughters by last sire.		6. 40	14, 227	917	

Conditions: 3 milkings.
6 female lines of descent with 3 successive crosses of proved sires.
7 female lines of descent with 2 successive crosses of proved sires.

PAUL AND J. S. ROLLER, TIMBERVILLE, VA., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
3	5	G	E	E	Penshurst
6	7	E	P	F	Fairview ;
9	7	U	F	F	Over The
2, 4, 5, 7, 8, 10, 11, 12	12	NP	NP	NP	
Total	31				
Number of daughters better than dams.		20	16	18	
		Percent	*Pounds*	*Pounds*	
Herd average of 42 cows		5. 63	9, 936	555	
Average of daughters by last sire.		6 90	10, 563	618	

Conditions: 2 milkings, 365 days.
1 female line of descent with 3 successive crosses of proved sires.
7 female line of descent with 2 successive crosses of proved sires.

LESH KELSEY & SON, HUNTINGTON, IND., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
1	12	F	G	E	Maybelle's Crescent 78095.
2	15	E	G	E	Burrow's Farm Polly Knight 99307.
3	12	G	F	G	Highland's Ajax 100112.
Total	39				
Number of daughters better than dams.		30	22	30	
		Percent	*Pounds*	*Pounds*	
Herd average of 54 cows		4. 93	9, 042	434	
Average of daughters by last sire.		5. 18	9, 553	493	

Conditions: 2 milkings.
5 female lines of descent with 3 successive crosses of proved sires.
11 female lines of descent with 2 successive crosses of proved sires.

3-SIRE HERDS—Continued

ADOLPH KNOTT, NILES, MICH., GUERNSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
2	7	G	G	E	Milky Way's May King of Oronoko 708853.
3	9	F	F	F	Jethro of Niles 119634, Oct. 6, 1925.
4	14	P	G	G	Luxerin Endicott 109208.
1, 5	6	NP	NP	NP	
Total	36				
Number of daughters better than dams.		17	25	25	
		Percent	*Pounds*	*Pounds*	
Herd average of 43 cows		4.94	8,681	420	
Average of daughters by last sire.		4.81	9,323	448	

Conditions: 2 milkings.
3 female lines of descent with 3 successive crosses of proved sires
10 female lines of descent with 2 successive crosses of proved sires.

OSBORNE FARMS, CANTON, N. C., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
	6	G	G	G	Lansdowne 18853.
	11	F	G	G	Bonita's King of Grape Lawn 65740.
	19	P	F	F	Millmount's Cavalier 97438.
2, 3, 6, 7, 8	15	NP	NP	NP	
Total	51				
Number of daughters better than dams.		29	28	28	
		Percent	*Pounds*	*Pounds*	
Herd average of 70 cows		4.76	12,273	581	
Average of daughters by last sire.		4.63	13,048	604	

Conditions: 3 milkings.
3 female lines of descent with 3 successive crosses of proved sires.
7 female lines of descent with 2 successive crosses of proved sires.

GEORGE W. ARPS, DEFIANCE, OHIO, JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	5	U	G	F	Maplewood Double Prince 232581.
3	9	E	U	E	Joans Heirloom of Purdue 250004.
4	8	F	G	G	Defiance Henry Volunteer 332663.
Total	22				
Number of daughters better than dams.		16	13	15	
		Percent	*Pounds*	*Pounds*	
Herd average of 31 cows		5.35	8,942	479	
Average of daughters by last sire.		5.48	9,916	541	

Conditions: 2 milkings.
8 female lines with 2 successive crosses of proved sires.
4 female lines with 3 successive crosses of proved sires.
No NP sires.

J. W. McHENRY, GRAFTON, OHIO, R. 2, JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	5	E	P	E	Orioles Fern's Torono of S. N. F. 212889.
3	21	G	G	E	Cocotte Raleigh Beechfield 243567.
4	8	G	F	G	Foreword's Successor 289663.
Total	34				
Number of daughters better than dams.		28	18	24	
		Percent	*Pounds*	*Pounds*	
Herd average of 46 cows		5.58	7,668	431	
Average of daughters by last sire.		5.95	8,898	530	

Conditions: 2 milkings, Dairy Herd Improvement Association and herd test.
4 female lines of descent with 3 successive crosses of proved sires.
6 female lines of descent with 2 successive crosses of proved sires.

CONNECTICUT REFORMATORY, CHESIRE, CONN., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
3	9	E	G	E	Far Oaks Sir Homestead Darki 263424.
4	26	U	F	F	North Star Noeltje Champion 43759
5	13	P	G	F	Pabst Sir Cornflower 563104.
2	0	NP	NP	NP	
Total	48				
Number of daughters better than dams.		28	23	25	
		Percent	*Pounds*	*Pounds*	
Herd average of 78 cows		3.83	12,655	484	
Average of daughters by last sire.		3.80	14,190	537	

Conditions: 2 and 3 milkings corrected to 2.
7 female lines of descent with 3 successive crosses of proved sires.
20 female lines of descent with 2 successive crosses of proved sires.

T. J. DEWEY, WESTFIELD, MASS., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	5	P	E	E	Fauvic's Gipsy Boy 215108.
3	5	E	E	E	Jolly Maid's Peter the Great 240801.
5	15	G	P	F	Josephine's Abigal Lad 289957.
4	2	NP	NP	NP	
Total	27				
Number of daughters better than dams.		18	17	18	
		Percent	*Pounds*	*Pounds*	
Herd average of 47 cows		5.21	7,960	412	
Average of daughters by last sire.		5.32	8,036	426	

Conditions: 2 milkings, Dairy Herd Improvement Association, 305 days.
1 female line of descent with 3 successive crosses of proved sires.
6 female lines of descent with 2 successive crosses of proved sires.

J. N. MARTIN, NEW PROVIDENCE, IOWA, JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
3	11	G	P	P	Sophie's Tormentor's Floss Duke 216516.
4	7	P	E	E	Hillside Pedro 25508.
5	7	U	E	E	Smoky Pogis 318391.
2	2	NP	NP	NP	
Total	27				
Number of daughters better than dams.		13	17	18	
		Percent	*Pounds*	*Pounds*	
Herd average of 41 cows		5.73	10,968	617	
Average of daughters by last sire.		5.79	13,097	750	

Conditions: 2 and 3 milkings corrected to 2.
3 female lines with 3 successive crosses of proved sires.
9 female lines with 2 successive crosses of proved sires.

L. RUSSELL BEARD, HEBRON, ILL., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
1	8	U	P	F	Veeman Homestead Pontiac 403102.
2	33	F	F	G	Admiral Ormsby Vale 414111.
4	24	U	E	E	M. M. Canary Marathon 550391.
3	4	NP	NP	NP	
Total	69				
Number of daughters better than dams.		39	40	42	
		Percent	*Pounds*	*Pounds*	
Herd average of 108 cows		3.47	9,617	333	
Average of daughters by last sire.		3.43	11,359	387	

Conditions: 2 milkings.
23 female lines of descent with 2 successive crosses of proved sires.
4 female lines of descent with 3 successive crosses of proved sires.

PHILIP STEFFANUS, DELAVAN, WIS., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
1	6	G	G	E	Sophie's 19th
3	6	F	E	E	Vive Glowm
4	6	P	F	U	Jolly Lassie I
2	4	NP	NP	NP	
Total	22				
Number of Daughters better than dams.		11	17	18	
		Percent	*Pounds*	*Pounds*	
Herd average of 35 cows		5.41	7,445	400	
Average of daughters by last sire.		4.89	8,437	410	

Conditions: 2 milkings, Dairy Herd Improvement Association, corrected to 305-day basis.
1 female line of descent with 3 successive crosses of proved sires.
5 female line of descent with 2 successive crosses of proved sires.

EUGENE HAM, VERBANK, N. Y., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Per centage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
3	12	G	G	G	Sir Johanna Jewel Gladi 372363.
4	26	P	G	G	Blacres Marmaduke Ormsby 445333.
5	15	F	E	E	Winterthur Donsegis Bano Ideal 546752.
2	1	NP	NP	NP	
Total	54				
Number of Daughters better than dams.		28	38	34	
		Percent	*Pounds*	*Pounds*	
Herd average of 73 cows		3.25	11,177	363	
Average of daughters by last sire.		3.30	12,389	408	

Conditions: 2 milkings.
4 female lines with 3 successive crosses of proved sires.
18 female lines with 2 successive crosses of proved sires.

GEORGE H. TIMMINS, WARE, MASS., GUERNSEY

	17	P	E	E	Golden Belle's Royal 84292.
	6	P	F	P	Promise of Gold of Ware 87479.
	10	G	G	E	Langwater Hardwick 141685.
	2	NP	NP	NP	
Total	35				
Number of daughters better than dams.		15	28	28	
		Percent	*Pounds*	*Pounds*	
Herd average of 54 cows		4.89	9,557	469	
Average of daughters by last sire.		5.12	10,497	537	

Conditions: 3 milkings.
3 female lines with 3 successive crosses of proved sires.
6 female lines with 2 successive crosses of proved sires.

FERNHEIM FARM, MONTROSE, PA., AYRSHIRE

4	8	P	E	G	Kates Robin 20177.
6 and 6½	22	F	U	F	Penshurst Sir Cuthbert 27722.
7	7	U	G	E	Penstate Sir Robert 34004.
2 and 2½, 3, 5, 8, 9	11	NP	NP	NP	
Total	48				
Number of daughters better than dams.		21	32	32	
		Percent	*Pounds*	*Pounds*	
Herd average of 62 cows		4.50	8,021	361	
Average of daughters by last sire.		4.57	8,917	407	

Conditions: Dairy Herd Improvement Association, 2 milkings, 205 days.
4 female lines of descent with 3 successive crosses of proved sires.
17 female lines of descent with 2 successive crosses of proved sires.

UNIVERSITY OF DELAWARE, NEWARK, DEL., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
2	16	E	U	G	Meadow Holm Ona Ormsby 230774.
4	24	P	G	F	Winterthur King Ormsby Envo 411070.
5	9	P	G	G	Winterthur Dad Boast Heboy 52686
3	3	NP	NP	NP	
Total	52				
Number of daughters better than dams.		24	30	33	
		Percent	Pounds	Pounds	
Herd average of 70 cows		3.33	14,330	475	
Average of daughters by last sire.		3.26	16,311	532	

Conditions: 2 to 4 milkings, corrected to 3.
4 female lines with 3 successive crosses of proved sires.
15 female lines with 2 successive crosses of proved sires.

HOMESTEAD FARMS, INC., STORMVILLE, N. Y., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
3	12	G	E	E	Nutmeg Colantha Sir Fayne 387685.
4	10	F	F	F	Count Paul Segis Posch 522060.
5	5	G	F	G	Korndyke Count Paul Segis Posch 604028.
2	1	NP	NP	NP	
Total	28				
Number of daughters better than dams.		20	18	21	
		Percent	Pounds	Pounds	
Herd average of 42 cows		3.41	10,684	363	
Average of daughters by last sire.		3.57	10,554	372	

Conditions: 2 milkings, Dairy Herd Improvement Association.
2 female lines with 3 successive crosses of proved sires.
8 female lines with 2 successive crosses of proved sires.

HENRY W. TREAT, TALLMADGE, OHIO, GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	7	F	E	E	Waddington Bravo 99047.
3	9	F	F	G	Milfords' Summit Raider 119824.
4	11	P	F	F	Caumsett Indian 167796.
Total	27				
Number of daughters better than dams.		14	17	21	
		Percent	Pounds	Pounds	
Herd average of 42 cows		5.10	8,556	434	
Average of daughters by last sire.		5.00	9,170	457	

Conditions: 2 milkings, Advanced Register and Dairy Herd Improvement Association.
1 female line with 3 successive crosses of proved sires.
8 female lines with 2 successive crosses of proved sires.

S. R. HEAD, HANNIBAL, MO., JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name
2	15	E	P	G	Le Gros 102780.
3	36	F	G	G	You'll Do Raleigh
4	13	E	P	G	Le Gros Torono 214
Total	64				
Number of daughters better than dams.		45	33	38	
		Percent	*Pounds*	*Pounds*	
Herd average of 85 cows		5.61	11,017	607	
Average of daughters by last sire.		6.21	11,022	682	

Conditions: 2 milkings corrected to 365 days.
1 female line with 4 successive crosses of proved sires.
12 female lines with 3 successive crosses of proved sires.
25 female lines with 2 successive crosses of proved sires.

LUCY R. SCUDDER, YAKIMA, WASH., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name
	7	P	G	F	Scotty of Scudder Ranch 135581.
	7	U	E	E	Fircrest LaFrance Royal 147632.
	11	U	F	U	Fircrest La France Prince 140870.
	1	NP	NP	NP	
Total	26				
Number of daughters better than dams.		13	15	14	
		Percent	*Pounds*	*Pounds*	
Herd average of 46 cows		4.98	8,509	420	
Average of daughters by last sire.		4.91	8,677	422	

Conditions: 2 milkings.
1 female line of descent with 3 successive crosses of proved sires.
7 female lines of descent with 2 successive crosses of proved sires.

R. B. CALDWELL, CHESTER, S. C., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name
3	8	P	E	E	Governor II of Les Grantes (Im 45452.
6	18	P	F	U	Gallant Cavalier 83960.
9	7	P	G	U	Imp. Betsey's Emblem 126428.
4, 5, 7, 8	4	NP	NP	NP	
Total	37				
Number of daughters better than dams.		12	23	21	
		Percent	*Pounds*	*Pounds*	
Herd average of 48 cows		5.18	11,798	605	
Average of daughters by last sire.		4.69	13,142	616	

Conditions: 3 milkings.
2 female lines with 3 successive crosses of proved sires.
16 female lines with 2 successive crosses of proved sires.

E. C. ADAMS, BLUE SPRINGS, MO., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires			Name of sire
		Percentage of butterfat	Production of—		
			Milk	Butterfat	
2	14	P	G	G	King Walker Lyons Johanna 347164.
3	14	P	F	F	Echo King Sylvia 267292.
4	5	F	F	F	Sir Aaggie DeKol Acme 42nd 469277.
Total	33				
Number of daughters better than dams.		13	22	20	
		Percent	*Pounds*	*Pounds*	
Herd average of 97 cows		3.54	16,881	595	
Average of daughters by last sire.		3.65	16,255	587	

Conditions: 2 milkings corrected to 3.
2 female lines with 3 successive crosses of proved sires.
25 female lines with 2 successive crosses of proved sires.

FRANK WOOD & SONS, PERRY, OHIO, JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	9	P	E	G	Oxford Ixia's Gamboge Boy 142439.
3	16	G	P	U	Marie's Sybil Prince 263240.
4	15	P	F	F	Bowlina's Rhoderick Dhix 317914.
Total	40				
Number of daughters better than dams.		22	22	24	
		Percent	*Pounds*	*Pounds*	
Herd average of 58 cows		5.29	8,018	421	
Average of daughters by last sire.		5.16	8,498	437	

Conditions: 2 milkings, Dairy Herd Improvement Association.
3 female lines with 3 successive crosses of proved sires.
15 female lines with 2 successive crosses of proved sires.

EDW. GRAVES, CONWAY, MASS., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
8	9	F	P	F	Goldie's Sophie's Tormentor 203144.
10	12	G	U	F	Pogis of Sunny Dell Farm 249841.
11	6	P	E	G	Madeline of Hillside's Boy 252846.
4, 5, 7, 9	9	NP	NP	NP	
Total	36				
Number of daughters better than dams.		22	19	22	
		Percent	*Pounds*	*Pounds*	
Herd average of 51 cows		5.49	8,745	478	
Average of daughters by last sire.		5.28	9,967	523	

Conditions: 2 milkings.
1 female line of decent with 3 successive crosses of proved sires.
5 female lines of decent with 2 successive crosses of proved sires.

WALTER FISHER, CRYSTAL FALLS, MICH., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
1	9	E	F	G	Ryonwood King of Midway, 416847.
2	12	F	F	F	Pabst DeKol Creator Tobe 406995.
3	8	F	F	F	Pabst Crusader Pontiac Duke 61873[illegible]
Total	29				
Number of daughters better than dams.		19	17	16	
		Percent	*Pounds*	*Pounds*	
Herd average of 38 cows		3.69	10,911	403	
Average of daughters by last sire.		3.75	11,046	415	

Conditions: 2 milkings.
2 female lines of decent with 3 successive crosses of proved sires.
15 female lines of decent with 2 successive crosses of proved sires.

H. L. SEVERE, PALMYRA, NEBR., HOLSTEIN

	6	F	F	F	King Yankee Pontiac C
	6	G	U	F	King Segis Gerben O 186986.
	20	F	F	G	N. P. Beauty Gerben Hengerveld 360809.
7	8	NP	NP	NP	
Total	40				
ber of daughters better n dams.		27	24	24	
		Percent	*Pounds*	*Pounds*	
average of 63 cows		3.46	13,487	466	
age of daughters by last		3.55	13,697	485	

Conditions: Dairy Herd Improvement Association, 2 and 3 milkings for sire 2, others 2 milkings.
2 female lines with 3 successive crosses of proved sires.
21 female lines with 2 successive crosses of proved sires.

HERMAN PLANKENHORN, HYDE PARK, N. Y., HOLSTEIN

4	19	F	F	F	King Jessie Echo 373960.
7	15	F	G	G	Echo King Netherland 529020.
8	15	F	F	F	King Mutual Rose 6th 532053.
3, 5	3	NP	NP	NP	
Total	52				
Number of daughters better than dams.		29	33	29	
		Percent	*Pounds*	*Pounds*	
Herd average of 78 cows		3.40	10,493	356	
Average of daughters by last sire.		3.38	10,740	362	

Conditions: Dairy Herd Improvement Association, 2 and 3 milkings corrected to 2.
2 female lines with 3 successive crosses of proved sires.
29 female lines with 2 successive crosses of proved sires.

MATT BIRKER, VINTON, IOWA, HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
4	9	G	P	P	Independence La
5	6	F	G	E	Oak Tritoma De
6	11	G	F	G	Sir Bess Nora La
2, 3, 7	8	NP	NP	NP	
Total	34				
Number of daughters better than dams.		23	14	20	
		Percent	Pounds	Pounds	
Herd average of 46 cows		3.84	14,343	550	
Average of daughters by last sire.		4.12	15,138	622	

Conditions: 2 milkings corrected to 3.
3 female lines with 3 successive crosses of proved sires.
10 female lines with 2 successive crosses of proved sires.

CLEMSON COLLEGE, CLEMSON COLLEGE, S. C., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	16	E	P	P	Sarcastic Hero Lad 310535.
5	24	P	F	F	Sir Colantha Ona Fayne 376935.
7	9	E	F	E	King Paul Canary Ormsby 356096.
3, 4, 6	8	NP	NP	NP	
Total.	57				
Number of daughters better than dams.		29	22	28	
		Percent	Pounds	Pounds	
Herd average of 71 cows		3.44	18,162	622	
Average of daughters by last sire.		3.53	19,498	687	

Conditions: 3 milkings.
1 female line with 4 successive crosses of proved sires.
10 female lines with 3 successive crosses of proved sires.
10 female lines with 2 successive crosses of proved sires.

RAUTH BROS., BOONVILLE, IND., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
1	7	G	U	F	Hambro's Sweet Boy of Robinhood 49144.
2	17	E	F	G	Fruitland Winner of Georgeland 102994.
3	19	E	P	F	Scottie of
Total	43				
Number of daughters better than dams.		40	18	20	
		Percent	Pounds	Pounds	
Herd average of 53 cows		4.89	8,586	420	
Average of daughters by last sire.		5.14	8,331	429	

Conditions: 2 milkings.
1 female line with 4 successive crosses of proved sires.
6 female lines with 3 successive crosses of proved sires.
18 female lines with 2 successive crosses of proved sires.

3-SIRE HERDS—Continued

CANTINE HOLLY VALLEY FARM, SAUGERTIES, N. Y., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
4	5	E	E	E	King Ormsby Ideal Duchess 423518.
6	8	F	F	F	De Kol Ormsby Dutchland Pontiac 550671.
7	5	U	U	U	Colantha Boy Pontiac Segis 620899.
3, 5	2	NP	NP	NP	
Total	20				
Number of daughters better than dams.		13	12	13	
		Percent	*Pounds*	*Pounds*	
Herd average of 39 cows		3.35	11,530	386	
Average of daughters by last sire.		3.42	10,462	356	

Conditions: 2 and 3 milkings corrected to 2.
2 female lines with 3 successive crosses of proved sires.
7 female lines with 2 successive crosses of proved sires.

H. D. ALLEBACH, TROPPE, PA., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
4	5	P	E	E	King Pontiac Segis Pandyke 279169.
5	5	F	E	G	Meadow Holm Hartog Finderne 330042.
6	6	G	E	E	Sir Aaggie Segis Cornucopia 290976.
3, 7, 8, 10	11	NP	NP	NP	
Total	27				
Number of daughters better than dams.		16	18	18	
		Percent	*Pounds*	*Pounds*	
Herd average of 34 cows		3.58	10,189	362	
Average of daughters by last sire		3.71	11,933	443	

Conditions: 2 milkings, Dairy Herd Improvement Association, 305 days.
7 female lines with 2 successive crosses of proved sires.

R. T. DAVIS, WEISER, IDAHO, HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
2	7	F	P	F	Segis Colai
3	11	G	P	F	Teton Sir S
5	7	F	F	G	Carnation
1, 4	6	NP	NP	NP	
Total	31				
Number of daughters better than dams.		21	15	16	
		Percent	*Pounds*	*Pounds*	
Herd average of 42 cows		3.41	15,514	518	
Average of daughters by last sire.		3.50	15,296	533	

Conditions: 3 milkings.
1 female lines of descent with 3 successive crosses of proved sires.
2 female lines of descent with 2 successive crosses of proved sires.

A. P. BIGELOW, MIDDLESEX, VT., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires			Name of sire
		Percentage of butterfat	Production of—		
			Milk	Butterfat	
3	17	G	P	F	King Bess Burke De Kol 408333.
7	18	F	U	F	Marathon Pontiac Ormsby 467042.
10	17	F	U	U	Sir Pasch Ormsby 597083.
1, 2, 4, 5, 6, 8, 9, 11	14	NP	NP	NP	
Total	66				
Number of daughters better than dams.		38	26	31	
		Percent	*Pounds*	*Pounds*	
Herd average of 107 cows		3.65	12,113	441	
Average of daughters by last sire.		3.73	12,176	463	

Conditions: Dairy Herd Improvement Association, 2 and 3 milkings corrected to 305 days.
8 female lines with 3 successive crosses of proved sires.
17 female lines with 2 successive crosses of proved sires.

R. E. FORT, NASHVILLE, TENN., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
9	6	F	E	E	Gamboge
15	7	E	F	E	Aristocra
18	9	U	G	G	Dreamin
2, 4, 5, 6, 7, 10, 11, 13, 14, 17, 19	15	NP	NP	NP	
Total	37				
Number of daughters better than dams.		24	23	30	
		Percent	*Pounds*	*Pounds*	
Herd average of 75 cows		5.65	10,841	613	
Average of daughters by last sire.		5.78	12,290	701	

Conditions: 3 milkings.
7 female lines with 2 successive crosses of proved sires.

CLOVERFIELDS FARM, ROUTE 5, OLY, WASH., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
3	12	U	G	G	Iota's St. Mawes Channel King 269881.
4	6	E	U	G	Oxford Sweeps Robert 273233.
5	5	U	E	E	Oxford's St. Mawes Lad 229831.
2	2	NP	NP	NP	
Total	25				
Number of daughters better than dams.		15	15	18	
		Percent	*Pounds*	*Pounds*	
Herd average of 50 cows		5.14	8,700	445	
Average of daughters by last sire.		5.36	9,023	484	

Conditions: 2 milkings, Dairy Herd Improvement Association.
7 female lines with 2 successive crosses of proved sires.

B. J. GILLMORE, BRISTOL, WIS., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	8	E	G	E	Carnation Echo Creator 330133.
4	7	F	U	F	King Cornucopia Boon Johanna 383151.
7	14	F	E	E	Gray View Joe Johanna 573290.
1, 3, 5, 6	6	NP	NP	NP	
Total	35				
Number of daughters better than dams.		24	22	24	
		Percent	*Pounds*	*Pounds*	
Herd average of 66 cows		3. 53	9, 819	347	
Average of daughters by last sire.		3. 59	11, 419	409	

Conditions: 2 milkings, Dairy Herd Improvement Association; corrected to 305 days.
9 female lines of descent with 2 successive crosses of proved sires.

J. H. SWANZEY, RIDOTT, ILL., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
3	10	U	E	E	Illini Homestead Pietertje Pieb 3rd 456330.
4	8	P	F	F	Logan Side Hill Ormsby Fayne 491027
5	5	G	P	F	King Colantha Schuiling 572742.
1, 2	6	NP	NP	NP	
Total	29				
Number of daughters better than dams.		13	16	17	
		Percent	*Pounds*	*Pounds*	
Herd average of 48 cows		3. 44	11, 394	389	
Average of daughters by last sire.		3. 62	12, 166	436	

Conditions: 2 milkings, Dairy Herd Improvement Association.
13 female lines of descent with 2 successive crosses of proved sires.

A. MISTR & SONS, RICHMOND, VA., GUERNSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	8	F	F	F	Mowen's Prince King 66372.
3	29	F	F	G	Winston Farm Gold Seeker 104962.
5	5	G	F	F	Raider's Ivanhoe 159163.
4	3	NP	NP	NP	
Total	45				
Number of daughters better than dams.		27	26	29	
		Percent	*Pounds*	*Pounds*	
Herd average of 77 cows		4. 74	8, 944	418	
Average of daughters by last sire.		4. 72	9, 508	443	

Conditions: 2 milkings, Dairy Herd Improvement Association and advanced register.
9 female lines with 2 successive crosses of proved sires.

3-SIRE HERDS—Continued

COLORADO STATE COLLEGE OF AGRICULTURE, FORT COLLINS, COLO., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name
8	10	F	F	G	Sir Ormsby Skyl 303888.
9	6	G	G	E	Columbine Pietertj
10	7	F	F	G	Triune Wayne Ros
2, 4, 6, 7, 11, 12	11	NP	NP	NP	
Total	34				
Number of daughters better than dams.		18	20	22	
		Percent	*Pounds*	*Pounds*	
Herd average of 50 cows		3.39	17,817	602	
Average of daughters by last sire.		3.42	20,215	687	

Conditions: 2 and 3 milkings corrected to 3 milkings, advanced register.
9 female lines of descent with 2 successive crosses of proved sires.

STATE INDUSTRIAL HOME, MUNCY, PA., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name
3	7	G	E	E	King Ambrosi 436616.
4	14	P	F	F	Loyalmead Ki 479952.
5	8	P	G	G	Onaco Piebe Po
2	2	NP	NP	NP	
Total	31				
Number of daughters better than dams.		15	22	23	
		Percent	*Pounds*	*Pounds*	
Herd average of 42 cows		3.47	13,614	471	
Average of daughters by last sire.		3.35	13,171	460	

Conditions: 2 and 3 milkings, no correction.
11 female lines with 2 successive crosses of proved sires.

C. S. BOGARDUS, CLINTON, ILL., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name
1	6		F	G	Chene King of Walnut Ridge 878
2	5		G	F	Rockingham Pompus 126679.
3	6		G	G	Noble Boy of Rockingham 166831
Total	17				
Number of daughters better than dams.			9	10	
			Pounds	*Pounds*	
Herd average of 29 cows			8,728	398	
Average of daughters by last sire.			9,687	430	

Conditions: 2 milkings, Dairy Herd Improvement Association.
5 female lines of descent with 2 successive crosses of proved sires.
Percent of butterfat was not reported.

QUAIL ROOST FARMS, ROUGEMONT, N. C., GUERNSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
II	9	E	F	G	Mimosa's Cavalier 37588.
III	9	G	F	G	Caumsett Taxpayer 145444.
IV	17	G	U	F	High Point Prince Maxim 104016.
Total	35				
Number of daughters better than dams.		30	17	21	
		Percent	*Pounds*	*Pounds*	
Herd average of 96 cows		5.32	12,367	657	
Average of daughters by last sire.		5.48	12,361	678	

Conditions: 3 milkings.
4 female lines of descent with 2 successive crosses of proved sires.

CHRIS YORDY, MORTON, ILL., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
1	5		E	E	Winner of East View 105080.
2	6		F	U	Lilah's King Peter 135044.
3	5		E	E	Sedgley Rilma's Ultimas 177248.
Total	16				
Number of daughters better than dams.			12	11	
		Percent	*Pounds*	*Pounds*	
Herd average of 25 cows			7,390	355	
Average of daughters by last sire.			7,939	389	

Conditions: Dairy Herd Improvement Association, 2 milkings.
8 female lines of descent with 2 successive crosses of proved sires.

TIOGA COUNTY FARM, WELLSBORO, PA., AYRSHIRE

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
5	10	P	G	F	Glenn Foerd Tiogan 29893.
6	12	F	E	E	Sycamore Caeron 37740.
7	6	G	F	G	Pennstate Marion's David 32076.
3	4	NP	NP	NP	
Total	32				
Number of daughters better than dams.		19	21	19	
		Percent	*Pounds*	*Pounds*	
Herd average of 57 cows		3.90	6,581	256	
Average of daughters by last sire.		3.95	6,967	278	

Conditions: 2 milkings, Dairy Herd Improvement Association. 305 days.
8 female lines with 2 successive crosses of proved sires.

PEDIGREED SEED CO., HARTSVILLE, S. C., GUERNSEY

Sire no.	Percentage of butterfat	Milk	Butterfat	Name of sire
	F	E	E	Grapelawn May King 45483.
	F	F	F	Amelia's Rose Gold of Ophir 80460.
	P	P	P	Coker Cavalier 111753.
2, 4, 6, 7, 9	NP	NP	NP	
Total				
Number of daughters better than dams.	29	24	24	
	Percent	*Pounds*	*Pounds*	
Herd average of 76 cows	5.25	11,937	627	
Average of daughters by last sire.	5.31	11,594	617	

Conditions: 3 milkings.
1 female line with 3 successive crosses of proved sires.
4 female lines with 2 successive crosses of proved sires.

2-SIRE HERDS

F. B. WEMPE, FRANKFORT, KANS., JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
1	7	E	E	E	Viola's You'll Do Butter King 192677.
2	9	G	G	E	White Way Prince Eminent 257735.
3	3	NP	NP	NP	
Total	19				
Number of daughters better than dams.		14	14	16	
		Percent	*Pounds*	*Pounds*	
Herd average of 30 cows		5.45	9,699	530	
Average of daughters by last sire.		5.59	10,483	583	

Conditions, 2 milkings.
5 female lines of descent with 2 successive crosses of proved sires.

DIETRICH & THORNTON, BREMEN, IND., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
1	6	P	E	E	Corixland's Confidence 85252.
3	16	E	U	G	Parks Roger 40034.
2	3	NP	NP	NP	
Total	25				
Number of daughters better than dams.		18	16	18	
		Percent	*Pounds*	*Pounds*	
Herd average of 41 cows		5.33	8,679	459	
Average of daughters by last sire.		5.71	8,779	498	

Conditions: 2 milkings.
7 female lines of descent with 2 successive crosses of proved sires.

G. & W. SHELDON, JEFFERSONVILLE, VT., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	7	G	E	E	Newton's Say
3	10	G	G	E	R. F. S. Torn
1, 4	5	NP	NP	NP	
Total	22				
Number of daughters better than dams.		18	13	16	
		Percent	*Pounds*	*Pounds*	
Herd average of 28 cows		5.69	6,839	389	
Average of daughters by last sire.		5.83	7,376	429	

Conditions: Dairy Herd Improvement Association, 2 milkings, 305 days.
5 female lines of descent with 2 successive crosses of proved sires.

CASTLE HILL FARM, WHITINSVILLE, MASS., AYRSHIRE

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
4		F	U	F	Glenford Violator 32529.
5		E	E	E	Penshurst Double Champion 36852
3 and 6		NP	NP	NP	
Total					
Number of daughters better than dams.		17	19	20	
		Percent	*Pounds*	*Pounds*	
Herd average of 59 cows		3.89	9,820	382	
Average of daughters by last sire.		4.08	11,822	484	

Conditions: 2 milkings.
6 female lines with 2 successive crosses of proved sires.

2-SIRE HERDS—Continued

GEO. TIEDEN & SON, ELKADER, IOWA, HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name
2	7	F	E	E	King Piebe Wilda
3	12	F	E	E	Walcowis Abbekii
4	3	NP	NP	NP	
Total	22				
Number of daughters better than dams.		14	17	17	
		Percent	*Pounds*	*Pounds*	
Herd average of 32 cows		3.46	16,086	555	
Average of daughters by last sire.		3.43	18,219	623	

Conditions: 2 milkings, corrected to 3.
3 female lines with 2 successive crosses of proved sires.

A. E. WISLER, LEETONIA, OHIO, GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name
2	6	G	F	G	Mayseeker of Myria Maree Farm 101794.
3	6	P	E	E	Franchester Dominant 155870.
Total	12				
Number of daughters better than dams.		6	9	10	
		Percent	*Pounds*	*Pounds*	
Herd average of 21 cows		5.25	7,706	397	
Average of daughters by last sire.		5.26	9,078	477	

Conditions: Dairy Herd Improvement Association.
4 female lines with 2 successive crosses of proved sires.

GEORGE STOLT, ROCHESTER, WASH., GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name
2	7	E	F	G	Hawthorne of Weedywold 56098.
3	5	F	E	E	Gaylord of Highland Place 93127.
4, 5	7	NP	NP	NP	
Total	19				
Number of daughters better than dams.		13	10	11	
		Percent	*Pounds*	*Pounds*	
Herd average of 35 cows		4.80	9,489	446	
Average of daughters by last sire.		4.52	11,810	533	

Conditions: 2 milkings, Dairy Herd Improvement Association.
5 female lines of descent with 2 successive crosses of proved sires.

F. B. BLACK, R. 6, MANSFIELD, OHIO, GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name
2	11	G	E	E	Sunnyvale Sun 103167.
3	8	P	G	G	Chedio Laddie 139827.
Total	19				
Number of daughters better than dams.		11	14	16	
		Percent	*Pounds*	*Pounds*	
Herd average of 38 cows		4.72	12,834	604	
Average of daughters by last sire.		4.65	14,514	674	

Conditions: 2 and 3 milkings corrected to 3.
4 female lines of descent with 2 successive crosses of proved sires.

2-SIRE HERDS—Continued

WALTER HENSE, SHEDD, OREG., JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
3	5	G	G	E	Marine's Lad of S. B. 141146.
5	6	G	G	G	Maiden's Masterman You'll do 279190.
1, 2, 4, 6, 7	7	NP	NP	NP	
Total	18				
Number of daughters better than dams.		15	12	13	
		Percent	*Pounds*	*Pounds*	
Herd average of 22 cows		5.38	8,978	488	
Average of daughters by last sire.		5.38	9,700	522	

Conditions: 2 milkings, 305 days.
5 female lines of descent with 2 successive crosses of proved sires.

IVORY KIMBALL, REHOBOTH, MASS., AYRSHIRE

4	6	F	E	E	Vi's Boun
5	9	G	E	E	Strathglas
2 and 3	5	NP	NP	NP	
Total	20				
Number of daughters better than dams.		13	14	14	
		Percent	*Pounds*	*Pounds*	
Herd average of 27 cows		4.05	9,443	382	
Average of daughters by last sire.		4.10	10,441	427	

Conditions: 2 milkings, Dairy Herd Improvement Association.
5 female lines with 2 successive crosses of proved sires.

STEPHEN SABINE (WESTFIELD FARM), GROTON, MASS., GUERNSEY

4	6	F	E	E	Roslyn's
5	7	G	G	G	Royals]
2, 3, 6	7	NP	NP	NP	
Total	20				
Number of daughters better than dams.		14	11	12	
		Percent	*Pounds*	*Pounds*	
Herd average of 28 cows		4.75	9,346	443	
Average of daughters by last sire.		4.76	9,680	459	

Conditions: 2 and 3 milkings corrected to 2.
11 female lines with 2 successive crosses of proved sires.

A. J. HEMPLER, GARNAVILLO, IOWA, GUERNSEY

3, 5	8	P	E	G	Dean of Kosh Konang Place 81529.
4	9	F	E	E	Colonel Cinnamon 131334.
2	1	NP	NP	NP	
Total	18				
Number of daughters better than dams.		12	16	15	
		Percent	*Pounds*	*Pounds*	
Herd average of 32 cows		5.14	9,975	510	
Average of daughters by last sire.		5.30	10,604	560	

Conditions: 2 milkings.
4 female lines of descent with 2 successive crosses of proved sires.

2-SIRE HERDS—Continued

S. M. MERRILL (ARGILLA FARMS), IPSWICH, MASS., GUERNSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
2	10	U	G	G	Langwater Sentinel 44805.
3	16	F	G	E	Dolly's Foremost of High Rock 678
4, 5, 6	5	NP	NP	NP	
Total	31				
Number of daughters better than dams.		19	21	22	
		Percent	*Pounds*	*Pounds*	
Herd average of 45 cows		5.53	10,079	550	
Average of daughters by last sire.		5.67	10,999	603	

Conditions: 3 milkings corrected to 2.
13 female lines of descent with 2 successive crosses of proved sires.

C. E. GRIFFITH, BIG CABIN, OKLA., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	13	E	G	E	Sir Johanna Bess Segis 187607.
5	10	E	F	G	Mt. Riga Sir Piebe Segis Paul 54712
3, 4	5	NP	NP	NP	
Total	28				
Number of daughters better than dams.		26	18	21	
		Percent	*Pounds*	*Pounds*	
Herd average of 50 cows		3.48	20,705	719	
Average of daughters by last sire.		3.68	20,997	770	

Conditions: 2, 3, and 4 milkings corrected to 3, 365 days.
5 female lines with 2 successive crosses of proved sires.

EMIL DREGER, R. D. 6, MADISON, WIS., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
3, 4	11	G	F	F	Prince Elba Ormsby 401492.
5, 6	21	G	G	E	Sir Frisby Ollie Ormsby
Total	32				
Number of daughters better than dams.		26	22	23	
		Percent	*Pounds*	*Pounds*	
Herd average of 47 cows		3.59	9,659	347	
Average of daughters by last sire.		3.69	10,568	389	

Conditions: 2 milkings, Dairy Herd Improvement Association, corrected to 305 days.
2 female lines of descent with 3 successive crosses of proved sires.
17 female lines of descent with 2 successive crosses of proved sires.

H. R. STEVENSON, SHAWNEETON, MO., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
3	7	G	U	F	Sultan's El
4	20	E	G	E	Mermaid's
2	3	NP	NP	NP	
Total	30				
Number of daughters better than dams.		22	19	22	
		Percent	*Pounds*	*Pounds*	
Herd average of 40 cows		5.50	6,762	373	
Average of daughters by last sire.		5.84	7,123	416	

Conditions: 2 milkings, corrected for age and length of record.
2 female lines with 3 successive crosses of proved sires.
7 female lines with 2 successive crosses of proved sires.

2-SIRE HERDS—Continued

C. L. REED, VERGENNES, VT., GUERNSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
1	27	G	P	F	Roughwood Rondo 117829.
2	6	P	E	E	Mount Hope Peveril 152261.
Total	33				
Number of daughters better than dams.		20	19	21	
		Percent	*Pounds*	*Pounds*	
Herd average of 54 cows		4.84	6,729	323	
Average of daughters by last sire.		4.66	8,262	383	

Conditions: Dairy Herd Improvement Association, 2 milkings, 305 days.
5 female lines of descent with 2 successive crosses of proved sires.

UTAH STATE MENTAL HOSPITAL, PROVO, UTAH, HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
5	14	F	U	F	Goliah of Hollywood 55th 501656.
6	7	G	E	E	Carnation Ormsby Valdessa 575525.
2, 3, 4	6	NP	NP	NP	
Total	27				
Number of daughters better than dams.		17	14	15	
		Percent	*Pounds*	*Pounds*	
Herd average of 54 cows		3.26	13,640	443	
Average of daughters by last sire.		3.36	14,475	486	

Conditions: 2 and 3 milkings corrected to 3, 305 days.
6 female lines with 2 successive crosses of proved sires.

EMIL YOUNGQUIST, MOUNT VERNON, WASH., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
2a	7	G	F	G	La Connor Pontiac Segis 21187
3a	6	E	F	G	Cascade Sire Jessie Piebe 425924
6a	4	NP	NP	NP	
Total	17				
Number of daughters better than dams.		13	[illegible]	10	
		Percent	*Pounds*	*Pounds*	
Herd average of 30 cows		3.30	17,284	576	
Average of daughters by last sire.		3.47	19,200	648	

Conditions: 2 milkings corrected to 3.
4 female lines of descent with 2 successive crosses of proved sires.

MRS. JOHN KENT KANE, GLENLOCH, PA., GUERNSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of—Milk	Rating of sires: Production of—Butterfat	Name of sire
3 and 7	9	E	F	G	Idella Vorden's
5 and 5½	21	E	F	G	Brookmead's 136386.
2, 4, 6	5	NP	NP	NP	
Total	35				
Number of daughters better than dams.		28	21	23	
		Percent	*Pounds*	*Pounds*	
Herd average of 62 cows		5.01	8,491	422	
Average of daughters by last sire.		5.25	8,679	455	

Conditions: 2 milkings.
4 female lines with 2 successive crosses of proved sires.

2-SIRE HERDS—Continued

L. H. MILLER, WATERLOO, IOWA, HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	6	F	F	G	Cornucopia
4	14	G	F	G	Tidy Sir Or
3	4	NP	NP	NP	
Total	24				
Number of daughters better than dams.		19	12	12	
		Percent	*Pounds*	*Pounds*	
Herd average of 36 cows		3.69	15,267	560	
Average of daughters by last sire.		3.79	16,450	621	

Conditions: 2 milkings corrected to 3.
9 female lines of descent with 2 successive crosses of proved sires.

CHAUNCEY ROSE SCHOOL, TERRE HAUTE, IND., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	6	P	F	F	Pabst Prilly Johanna
3	6	G	G	E	King Piebe 33rd 4397
Total	12				
Nnmber of daughters better than dams.		6	6	8	
		Percent	*Pounds*	*Pounds*	
Herd average of 19 cows		3.33	12,874	432	
Average of daughters by last sire.		3.49	14,501	506	

Conditions: 2 milkings corrected to 3.
4 female lines of descent with 2 successive crosses of proved sires.

SISTERS OF PROVIDENCE, ST. MARY-OF-THE-WOODS, IND., HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
3	14	P	G	F	King Piebe 24th 427882.
4	18	E	G	E	Sunny Roso Piebe 5730'
1, 2	6	NP	NP	NP	
Total	38				
Number of daughters better than dams.		21	22	22	
		Percent	*Pounds*	*Pounds*	
Herd average of 74 cows		3.37	11,037	372	
Average of daughters by last sire.		3.62	12,114	439	

Conditions: 2 milkings.
9 female lines with 2 successive crosses of proved sires.

E. V. STUART, LEES SUMMIT, MO., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	6	P	E	G	Anaesthetic's Flying Fox 231226.
3	8	F	G	G	Mern Golden Nobleman 273816.
Total	14				
Number of daughters better than dams.		5	10	9	
		Percent	*Pounds*	*Pounds*	
Herd average of 22 cows		5.28	8,484	449	
Average of daughters by last sire.		5.34	8,798	473	

Conditions: 2 milkings corrected to 365 days.
8 female lines with 2 successive crosses of proved sires.

2-SIRE HERDS—Continued

PHOENIX INDIAN SCHOOL, PHOENIX, ARIZ., HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Rating of sires: Production of— Milk	Rating of sires: Production of— Butterfat	Name of sire
2	18	G	U	F	King Colantha Alcartra Prilly 451718.
3	12	G	F	G	Sir Inka May 12th 524279.
4	3	NP	NP	NP	
Total	33				
Number of daughters better than dams.		24	20	21	
		Percent	*Pounds*	*Pounds*	
Herd average of 61 cows		3.16	16,112	504	
Average of daughters by last sire.		3.30	17,183	569	

Conditions: 2 milkings corrected to 3.
6 female lines with 2 successive crosses of proved sires.

TUDOR L. HOLCOMB, WEST GRAMBY, CONN., GUERNSEY

2	17	F	G	G	Aphasia's Teddy R. of Hillstead 110641.
3	9	F	U	F	Belle's Rose King of Md. Fair 144221.
4	2	NP	NP	NP	
Total	28				
Number of daughters better than dams.		17	16	19	
		Percent	*Pounds*	*Pounds*	
Herd average of 48 cows		4.78	8,792	419	
Average of daughters by last sire.		4.89	9,302	453	

Conditions: 2 milkings, Dairy Herd Improvement Association.
6 female lines of descent with 2 successive crosses of proved sires.

BERT LEAS, JR., GROVEPORT, OHIO, JERSEY

2	6	P	E	G	Roses Majesty Bo
3	20	G	F	F	Social Sybils Gran
Total	26				
Number of daughters better than dams.		16	15	16	
		Percent	*Pounds*	*Pounds*	
Herd average of 38 cows		5.49	8,872	480	
Average of daughters by last sire.		5.59	9,018	504	

Conditions: 2 milkings, Dairy Herd Improvement Association and herd test.
3 female lines of descent with 3 successive crosses of proved sires.
10 female lines of descent with 2 successive crosses of proved sires.

L. S. FOWLER & SON, BRISTOL, WIS., HOLSTEIN

2	8	G	F	G	King Cornucopia Boon Segis 439039.
3	8	P	G	F	Prince Homestead Bess Pontiac 522979.
1, 4, 5	5	NP	NP	NP	
Total	21				
Number of daughters better than dams.		8	12	14	
		Percent	*Pounds*	*Pounds*	
Herd average of 30 cows		3.78	9,705	367	
Average of daughters by last sire.		3.55	10,862	382	

Conditions: 2 milkings, Dairy Herd Improvement Association, converted to 305 days.
4 female lines of descent with 2 successive crosses of proved sires.

2-SIRE HERDS—Continued

E. W. RUEHS, CALEDONIA, MICH., GUERNSEY

Sire no.	Pairs of daughters and dams	Rating of sires: Percentage of butterfat	Production of— Milk	Production of— Butterfat	Name of sire
1	9	P	G	G	Susie's Sir Lau 64502.
3	14	F	F	F	Cavalier of Oron
2	1	NP	NP	NP	
Total	24				
Number of daughters better than dams.		10	15	14	
		Percent	*Pounds*	*Pounds*	
Herd average of 35 cows		4.99	9,064	450	
Average of daughters by last sire.		5.04	9,446	471	

Conditions: 2 milkings, Dairy Herd Improvement Association.
7 female lines of descent with 2 successive crosses of proved sires.

SYD PENN, TROY, MO., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	17	F	F	G	Troy Lad 210507.
3	8	F	F	F	Financial Raleigh O'Colman.
Total	25				
Number of daughters better than dams.		15	16	15	
		Percent	*Pounds*	*Pounds*	
Herd average of 39 cows		5.49	8,585	470	
Average of daughters by last sire.		5.62	8,992	498	

Conditions: 2 milkings corrected to 365 days.
1 female line of descent with 3 successive crosses of proved sire.
10 female line of descent with 2 successive crosses of proved sire.

W. F. RANNEY, WESTMINSTER, VT., JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	22	P	E	G	Upwey's
3	11	G	U	F	Upwey Compound Owl's Vicar 316141.
1, 4	2	NP	NP	NP	
Total	35				
Number of daughters better than dams.		13	23	23	
		Percent	*Pounds*	*Pounds*	
Herd average of 46 cows		5.00	8,319	415	
Average of daughters by last sire.		5.11	8,601	440	

Conditions: 2 milkings, Dairy Herd Improvement Association, 305 days.
10 female lines of descent with 2 successive crosses of proved sires.

H. H. HOFFMAN, R. 5, ABILENE, KANS., AYRSHIRE

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2, 3	8	F	G	E	Silver Good Gift 24428.
4	22	G	E	E	Alta Crest Play Safe 29851.
1	2	NP	NP	NP	
Total	32				
Number of daughters better than dams.		21	21	22	
		Percent	*Pounds*	*Pounds*	
Herd average of 42 cows		3.84	7,705	292	
Average of daughters by last sire.		3.91	8,417	317	

Conditions: 2 milkings.
1 female line with 4 successive crosses of proved sires.
4 female lines with 3 successive crosses of proved sires.
13 female lines with 2 successive crosses of proved sires.

GARDNER STATE COLONY, GARDNER, MASS.: GRADE, HOLSTEIN

Sire no.	Pairs of daughters and dams	Rating of sires			Name of sire
		Percentage of butterfat	Production of—		
			Milk	Butterfat	
2	12	P	G	F	Prince Almira Mobel 240723.
3	7	G	E	E	Dutchland Creamelle Korigen Duke 326672.
4	7	G	G	E	Mount Herman Archibald Ando 438004.
5	14	F	G	G	Mount Herman Archibald Butterboy 438013.
7	5	F	G	F	Howcofit Korndyke Mobel 502209.
8	13	P	U	P	Howcofit Prince Mobel 517079.
9	5	F	F	G	Prison Camp King Pietertje Alcartra 542485.
6	4	NP	NP	NP	
Total	67				
Number of daughters better than dams.		38	44	45	
		Percent	*Pounds*	*Pounds*	
Herd average of 100 cows		3.71	11,825	438	
Average of daughters by last sire.		3.77	13,546	511	

Conditions: 3 milkings corrected to 2.
6 female lines of descent with 3 successive crosses of proved sires.
39 female lines of descent with 2 successive crosses of proved sires.

ALLEGHENY WORK HOUSE, BLAWNOX, PA.: GRADE, JERSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2 and 2A	5	U	E	E	Oxford Napoleon
3 and 3A	13	E	F	G	No. 147.
4 and 4A	23	G	E	E	No. 148.
6	5	P	E	G	Workhouse Drea
1½ and 5	3	NP	NP	NP	
Total	49				
Number of daughters better than dams.		32	33	39	
		Percent	*Pounds*	*Pounds*	
Herd average of 76 cows		5.45	7,104	386	
Average of daughters by last sire.		5.15	8,276	428	

Conditions: 2 milkings, Dairy Herd Improvement Association, 305 days.
10 female lines with 3 successive crosses of proved sires.
32 female lines with 2 successive crosses of proved sires.

J. W. N. GRUBER, SHIPPENVILLE, PA., GRADE GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	9	E	P	G	Cub (not registered).
4	7	P	E	G	Tom (not registered).
6	24	F	F	G	Thorton's White Light 125574
3, 7	4	NP	NP	NP	
Total	44				
Number of daughters better than dams.		31	21	29	
		Percent	*Pounds*	*Pounds*	
Herd average of 67 cows		4.94	8,083	397	
Average of daughters by last sire.		5.08	8,747	443	

Conditions: 2 milkings, Dairy Herd Improvement Association, 305 days.
2 female lines with 3 successive crosses of proved sires.
11 female lines with 2 successive crosses of proved sires.

HAGG BROS., REEDVILLE, OREG.: GRADE, JERSEY

Sire no.	Pairs of daughters and dams	Rating of sires			Name of sire
		Percentage of butterfat	Production of— Milk	Production of— Butterfat	
3	30	F	E	E	Madrid Tristram's St. Mawes 237485.
4	5	F	E	E	Putman's Bull.
1, 2	4	NP	NP	NP	
Total	39				
Number of daughters better than dams.		22	30	33	
		Percent	*Pounds*	*Pounds*	
Herd average of 63 cows		5.64	8,178	463	
Average of daughters by last sire.		5.74	9,953	569	

Conditions: 2 milkings, Dairy Herd Improvement Association.
4 female lines with 2 successive crosses of proved sires.

JOHN GEINGER, TILLAMOOK, OREG.: GRADE, GUERNSEY

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
1	14	E	G	E	Heroine's Walter of May Rose 73264.
2	9	E	P	F	Giant Oak Oregonian 130124.
Total	23				
Number of daughters better than dams.		21	12	16	
		Percent	*Pounds*	*Pounds*	
Herd average of 33 cows		4.82	12,514	594	
Average of daughters by last sire.		5.50	11,471	615	

Conditions: Dairy Herd Improvement Association, 365 days.
1 female line of descent with 3 successive crosses of proved sires.
7 female lines of descent with 2 successive crosses of proved sires.

MASSACHUSETTS STATE PRISON, NORFORK, MASS.: GRADE, HOLSTEIN

Sire no.	Pairs of daughters and dams	Percentage of butterfat	Milk	Butterfat	Name of sire
2	22	U	G	E	Duke Pearl Asiatic 444012.
3	8	E	U	G	Count Colantha Ormsby Posch 553496.
4	5	F	E	E	Midc Sir Ormsby Pietertje 588
5	4	NP	NP	NP	
Total	39				
Number of daughters better than dams.		22	24	28	
		Percent	*Pounds*	*Pounds*	
Herd average of 65 cows		3.66	11,963	437	
Average of daughters by last sire.		3.60	14,660	528	

Conditions: 3 milkings.
10 female lines of descent with 2 successive crosses of proved sires.

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Puerto Rico Agricultural Experiment Station: S. Basherov.
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[1] Resigned.
Workers who have published results of studies.

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Chicago University: Sewall Wright.
Harvard: W. E. Castle.[2]
Holstein-Friesian Association: E. E. Heizer, H. W. Norton, Jr.
Johns Hopkins: Raymond Pearl.
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- Pontiac, S. C.: E. W. Faires.
- Woodward, Okla.: A. G. Van Horn.
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- Lewisburg, Tenn.: J. A. Simms.
- Logan, Utah.: G. Q. Bateman.[3]
- Puyallup, Wash.: R. E. Hodgson.[4]

[2] Retired.
[3] Cooperative with Utah Agricultural Experiment Station.
[4] Cooperative with Western Washington Agricultural Experiment Station.

Statistics

Prepared under the direction of the Yearbook Statistical Committee: Joseph A. Becker, chairman, Paul Froehlich, secretary, S. W. Mendum, L. D. Howell, F. J. Hosking, and G. W. Sprague

The statistical section of this Yearbook includes only a selected group of the more important agricultural statistics of the United States, and of the world so far as the agriculture of this country is concerned. The series given here is limited to subjects which experience indicates are of relatively universal public interest.

NOTICE

THE usual tables of summarized or detailed statistics, previously appearing in the Yearbook, appear this year in a separate volume entitled: "Agricultural Statistics, 1936." The statistics included in previous issues of the Yearbook were in more detail than was required by many readers. It seemed preferable to publish these details in separate form, rather than in a book intended for wide distribution. This separate volume is available without cost from the Department of Agriculture, as long as the supply lasts, or it may be purchased from the Government Printing Office.

For greater detail on individual commodities, the commodity handbooks and the statistical bulletin series may be consulted. Statistical Bulletins 37 to 52, inclusive, have been published during the last 4 years and relate to wheat, corn, cotton, fruits and vegetables, forest products, and cold-storage holdings.

For current statistics, to supplement the other statistics, the following sources may be used: (1) Crops and Markets, a monthly publication of the Department carrying the latest current statistics on agriculture in the United States; (2) Foreign Crops and Markets, issued weekly by the Bureau of Agricultural Economics and devoted to current world statistics of crops, livestock, and markets; (3) foreign commodity reports, showing the latest world information on single commodities and released when important information is received; (4) The Agricultural Situation, issued monthly; (5) The Price Situation, published monthly, summarizing business conditions and the price situation for important commodities; (6) market news reports of the Bureau of Agricultural Economics, issued daily, weekly, monthly, quarterly, or at irregular intervals at Washington or at the principal markets; (7) an annual report on the number of bales of cotton of each grade and staple carried over on August 1 and four similar reports, periodically during the season, on cotton ginned up to specific dates in each of the principal cotton-producing States. Requests for any of these publications may be addressed to Division of Economic Information, Bureau of Agricultural Economics, Washington, D. C.

TABLE 1.—*Crop and livestock summary: Acreage, production, numbers, and value, average 1928–32, and annual 1934 and 1935, with livestock data for 1936*

Crop	Acreage harvested			Production				Farm value	
	Average, 1928–32	1934	1935[1]	Unit	Average, 1928–32	1934	1935[1]	1934	1935[1]
	1,000 acres	*1,000 acres*	*1,000 acres*		*Thousands*	*Thousands*	*Thousands*	*1,000 dollars*	*1,000 dollars*
Corn, all	102,768	87,795	92,727	Bushel	2,562,147	1,377,126	2,202,852	1,124,321	1,271,089
Wheat, all	59,885	42,249	49,826	do	860,570	496,929	603,199	420,808	505,394
Winter	39,454	32,968	31,000	do	618,186	405,552	433,447	341,916	353,688
All spring	20,431	9,281	18,826	do	242,384	91,377	169,752	78,892	151,706
Durum	4,805	990	2,644	do	53,909	7,086	26,777	7,211	20,109
Other spring	15,626	8,291	16,182	do	188,476	84,291	142,975	71,681	131,597
Oats	39,887	30,172	39,714	do	1,217,646	525,889	1,195,435	252,152	333,960
Barley	12,739	7,095	12,858	do	282,841	118,348	292,249	81,899	111,271
Rye	3,296	1,942	4,063	do	38,655	16,045	57,936	11,445	22,248
Buckwheat	568	478	496	do	8,277	9,042	8,234	5,296	4,404
Flaxseed	2,757	969	2,071	do	15,961	5,213	14,931	8,858	21,983
Rice	924	781	784	do	43,017	38,296	38,452	30,332	24,011
Grain sorghums[2]	6,855	7,569	10,470	do	93,764	34,542	103,494	33,766	52,674
Cotton, lint	40,554	26,987	27,331	Bale	14,666	9,636	10,734	595,602	593,677
Cottonseed	------	------	------	Ton	6,520	4,282	4,775	148,986	150,877
Hay, all	67,091	60,740	64,488	do	80,384	57,028	87,620	784,795	637,478
Hay, all tame	53,725	51,828	52,026	do	69,591	52,269	75,619	729,665	582,480
Hay, wild	13,366	8,912	12,462	do	10,793	4,759	12,001	55,130	54,998
Sweet sorgos[3]	2,139	3,557	3,867	do	3,437	3,253	5,536	34,008	32,267
Timothy seed	410	126	662	Bushel	1,560	262	2,849	1,714	3,332
Clover seed (red and alsike).	1,070	964	754	do	1,563	1,099	1,015	12,096	8,668
Sweetclover seed	236	189	155	do	891	626	559	2,575	1,533
Lespedeza seed[4]	[5] 123	247	250	do	[5] 921	1,913	1,736	3,054	2,365
Alfalfa seed	341	392	360	do	823	821	823	8,430	6,694
Beans, dry edible	1,760	1,399	1,843	Bag[6]	11,858	10,369	13,799	34,996	36,876
Soybeans[7]	793	1,216	2,379	Bushel	11,658	18,627	39,637	19,034	29,121
Cowpeas[7]	579	654	638	do	4,773	5,296	5,816	7,809	7,791
Peanuts[7]	1,346	1,571	1,642	Pound	938,880	1,063,035	1,264,455	35,143	39,771
Velvetbeans[2]	1,285	1,595	1,557	Ton	537	659	714	8,244	8,010
Potatoes	3,243	3,312	3,271	Bushel	363,367	385,421	356,406	180,761	208,713
Sweetpotatoes	729	762	778	do	63,841	67,400	69,853	53,843	48,511
Tobacco	1,874	1,278	1,437	Pound	1,432,845	1,081,629	1,296,810	224,699	237,011
Sorgo sirup	197	228	213	Gallon	12,348	13,788	12,438	7,043	6,823
Sugarcane, Louisiana	186	249	258	Ton	3,006	3,735	4,486	9,326	11,875
Cane sirup	105	139	145	Gallon	17,149	22,290	24,699	10,134	10,168
Sugar beets	717	770	771	Ton	8,118	7,519	7,984	38,776	41,100
Maple sugar	[8] 12,728	[8] 12,158	[8] 12,496	Pound	1,838	1,271	1,704	314	452
Maple sirup	[8] 12,728	[8] 12,158	[8] 12,496	Gallon	2,682	2,395	3,377	3,192	4,804
Broomcorn	320	302	489	Ton	47	32	60	5,281	4,800
Hops	23	37	39	Pound	28,011	[9] 41,195	[9] 47,080	5,682	5,018
Apples, total	------	------	------	Bushel	[9] 161,333	120,670	168,465	106,454	120,936
Apples, commercial	------	------	------	do	97,895	73,534	91,701	64,068	65,462
Peaches, total	------	------	------	do	[9] 56,451	[9] 45,665	52,380	35,035	44,026
Pears, total	------	------	------	do	[9] 23,146	[9] 23,490	21,255	16,195	13,485
Grapes, total[10]	------	------	------	Ton	[9] 2,200	1,931	[9] 2,327	37,255	33,865
Cherries (12 States)	------	------	------	do	[9] 108	114	117	6,781	8,694
Plums and prunes, fresh (5 States).	------	------	------	do	[9] 140	137	104	3,432	3,294
Prunes, dried (3 States).	------	------	------	do	[9] 226	200	280	16,110	16,647
Oranges (7 States)	------	------	------	Box	48,816	64,937	52,928	88,389	101,264
Grapefruit (4 States)	------	------	------	do	14,730	21,357	17,945	17,772	20,956
Lemons (California)	------	------	------	do	7,251	10,506	8,000	15,444	19,200
Cranberries	28	27	27	Barrel	581	443	486	4,743	5,732
Pecans	------	------	------	Pound	59,983	40,375	95,340	5,013	5,889
Commercial truck crops:									
Artichokes	7.8	8.4	9.0	Box	873	1,060	1,017	1,060	1,729
Asparagus, total	97.6	112.9	109.8	------	------	------	------	10,034	10,882
For market	57.0	68.0	59.4	Crate	4,427	5,388	4,625	6,808	6,572
For manufacture	40.6	44.9	50.4	Ton	58.1	48.5	57.0	3,226	4,310
Beans, lima, total	[5] 35.8	37.0	36.6	------	------	------	------	1,670	1,762
For market	9.2	12.4	10.0	Bushel	601	580	602	648	815
For manufacture	[5] 25.6	24.6	26.6	Ton	[5] 12.6	17.4	15.2	1,022	947
Beans, snap, total	161.9	192.2	193.0	------	------	------	------	13,404	15,541
For market	107.2	147.1	144.4	Bushel	[9] 9,447	[9] 13,612	[9] 11,824	10,679	12,095
For manufacture	54.7	45.1	48.6	Ton	73.1	66.1	80.2	2,725	3,446
Beets, total	[5] 16.4	19.0	18.5	------	------	------	------	1,426	1,393
For market	9.6	12.2	10.5	Bushel	[9] 1,770	2,326	[9] 1,682	1,006	911
For manufacture	[5] 6.3	6.8	8.0	Ton	[5] 35.9	40.1	46.3	420	482

Table 1.—*Crop and livestock summary: Acreage, production, numbers, and value, average 1928–32, and annual 1934 and 1935, with livestock data for 1936*—Con.

Crop	Acreage harvested			Production				Farm value	
	Average, 1928–32	1934	1935 [1]	Unit	Average, 1928–32	1934	1935 [1]	1934	1935 [1]
	1,000 acres	*1,000 acres*	*1,000 acres*		*Thousands*	*Thousands*	*Thousands*	*1,000 dollars*	*1,000 dollars*
Cabbage, total	143.7	176.7	138.3	do	[9] 1,010.4	[9] 1,230.4	[9] 926.4	9,590	12,106
For market	123.5	151.0	121.5	do	[9] 844.7	[9] 1,014.7	[9] 790.1	8,221	11,406
For sauerkraut	20.2	25.7	16.8	do	165.7	215.7	136.3	1,369	700
Cantaloups	122.9	96.5	112.7	Crate	[9] 16,763	12,087	[9] 13,322	13,351	11,927
Carrots	27.6	35.9	36.8	Bushel	[9] 10,127	13,005	[9] 13,362	6,503	7,503
Cauliflower	27.4	28.5	28.7	Crate	[9] 6,658	6,621	[9] 7,150	3,944	5,023
Celery	32.6	32.3	34.2	do	[9] 9,168	8,642	8,322	10,492	14,973
Corn, sweet, total	336.0	312.1	423.8					5,471	9,019
For market (New Jersey only).	22.0	24.5	24.5	Ear	102,610	129,850	117,600	1,260	1,058
For manufacture	314.0	287.6	399.3	Ton	628.0	498.0	854.6	4,211	7,961
Cucumbers, total	126.0	121.9	133.2					5,090	5,790
For market	46.8	42.2	43.8	Bushel	[9] 4,607	3,493	[9] 4,301	3,000	3,182
For pickles	79.2	79.7	89.4	do	4,972	4,404	5,032	2,090	2,608
Eggplant	3.5	3.7	3.4	do	772	746	707	445	446
Kale (Virginia only)	1.9	1.5	1.5	do	766	225	285	90	100
Lettuce	155.3	154.4	153.9	Crate	[9] 19,163	[9] 19,294	19,580	25,778	28,213
Onions	84.4	84.8	99.0	Sack	[9] 13,247	[9] 13,007	[9] 14,140	14,538	18,077
Peas, total	303.5	351.0	424.8					18,809	23,182
For market	80.0	101.1	112.2	Bushel	[9] 6,088	7,667	[9] 8,371	10,521	9,443
For manufacture	223.5	249.9	312.6	Ton	182.1	165.4	265.1	8,288	13,739
Peppers	16.6	15.2	17.3	Bushel	3,829	3,499	3,217	2,746	2,260
Pimientos for manufacture.	8.5	9.5	13.6	Ton	15.0	15.8	20.8	468	647
Spinach, total	58.9	69.9	72.7					4,835	6,140
For market	47.8	54.6	56.5	Bushel	[9] 12,580	10,946	9,839	4,345	5,480
For manufacture	11.1	15.3	16.2	Ton	52.7	41.3	52.6	490	660
Tomatoes, total	466.5	525.9	624.9					38,942	41,854
For market	150.7	162.6	169.8	Bushel	[9] 16,891	[9] 18,319	18,903	22,040	22,351
For manufacture	315.8	363.3	455.1	Ton	129.3	1,407.5	1,673.4	16,902	19,503
Watermelons	225.1	192.3	204.4	Melon	[9] 70,053	[9] 48,176	[9] 57,254	5,194	5,322
Total truck crops	2,452.0	2,581.6	2,890.1					193,880	223,889
For market (21 crops).	1,358.9	1,429.2	1,453.5					152,669	168,886
For manufacture (11 crops).	1,093.1	1,152.4	1,436.6					41,211	55,003
Potatoes, early	318.2	307.8	272.1	Bushel	42,127	42,799	[9] 38,094	23,779	19,451
Strawberries	181.6	197.7	163.3	Crate	[9] 12,127	[9] 13,152	[9] 11,681	23,684	27,308
Total 44 crops	355,544	286,513	327,661						
Total 64 crops								1,779,335	5,118,444

Farm animals	Number Jan. 1			Farm value per head			Farm value	
	Average, 1928–32	1935	1936 [1]	Average, 1928–32	1935	1936	1935	1936 [1]
	Thousands	*Thousands*	*Thousands*	*Dollars*	*Dollars*	*Dollars*	*1,000 dollars*	*1,000 dollars*
Horses and colts	13,725	11,861	11,637	64.10	77.05	96.79	913,870	1,126,400
Mules and mule colts	5,394	4,822	4,685	75.23	99.34	120.42	478,998	564,186
Cattle and calves	61,200	68,529	68,213	46.17	20.22	34.09	1,385,948	2,325,586
Total sheep and lambs	50,482	52,251	51,690	7.69	4.31	6.38	225,282	329,693
Hogs, including pigs	58,151	39,004	42,541	11.41	6.31	12.68	246,196	539,561
Total							3,250,294	4,885,426

[1] Preliminary.
[2] All purposes.
[3] For hay and forage, but not included in tame hay.
[4] Bushels of 25 pounds.
[5] Short-time average.
[6] Bags of 100 pounds.
[7] Covers only mature crop gathered for the beans, peas, or peanuts.
[8] 1,000 trees tapped.
[9] Includes some quantities not harvested. Prices and value are computed on the harvested crop.
[10] Production is the total for fresh fruit, juice, and raisins.

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Table 2.—*Total acreage and total farm value of principal crops, by States, 1934 and 1935*

State and division	Total acreage of 44 crops (excluding duplications)[1]		Total farm value of 64 crops[1]	
	1934	1935[2]	1934	1935[2]
	Acres	*Acres*	*1,000 dollars*	*1,000 dollars*
Maine	1, 335, 000	1, 343, 000	27, 994	35, 721
New Hampshire	422, 000	430, 000	9, 090	8, 022
Vermont	1, 074, 000	1, 090, 000	24, 539	19, 561
Massachusetts	409, 000	424, 500	18, 919	19, 061
Rhode Island	57, 000	59, 200	2, 044	2, 054
Connecticut	341, 200	346, 100	15, 965	15, 759
New York	6, 548, 200	6, 610, 300	142, 760	131, 607
New Jersey	668, 000	685, 000	34, 338	34, 448
Pennsylvania	5, 990, 200	6, 096, 700	142, 993	135, 232
North Atlantic	16, 844, 600	17, 084, 800	418, 642	401, 465
Ohio	8, 886, 300	9, 171, 300	167, 338	161, 936
Indiana	9, 525, 800	10, 061, 400	153, 712	146, 876
Illinois	15, 734, 600	17, 692, 100	218, 569	273, 931
Michigan	7, 189, 000	7, 416, 000	130, 473	127, 155
Wisconsin	9, 091, 500	9, 778, 200	177, 797	153, 504
Minnesota	16, 437, 400	19, 514, 700	183, 984	211, 207
Iowa	18, 235, 400	20, 883, 400	248, 340	289, 230
Missouri	10, 997, 600	10, 797, 300	103, 569	127, 712
North Dakota	9, 287, 500	18, 544, 800	49, 438	112, 116
South Dakota	5, 471, 600	15, 905, 100	28, 182	96, 615
Nebraska	15, 253, 000	20, 158, 000	83, 750	157, 809
Kansas	17, 497, 800	17, 926, 100	119, 155	126, 703
North Central	143, 607, 500	177, 848, 400	1, 664, 307	1, 984, 794
Delaware	377, 000	383, 000	11, 163	9, 570
Maryland	1, 618, 300	1, 681, 000	45, 585	44, 017
Virginia	3, 755, 300	3, 865, 100	105, 178	102, 432
West Virginia	1, 417, 700	1, 422, 000	29, 646	28, 696
North Carolina	6, 020, 000	6, 152, 000	262, 973	246, 348
South Carolina	4, 197, 000	4, 344, 000	105, 858	108, 623
Georgia	8, 924, 600	9, 218, 000	156, 663	157, 353
Florida	1, 236, 700	1, 269, 800	77, 110	78, 640
South Atlantic	27, 546, 600	28, 334, 900	794, 176	775, 679
Kentucky	4, 743, 000	4, 649, 000	118, 840	108, 274
Tennessee	5, 481, 600	5, 356, 300	124, 423	99, 948
Alabama	7, 508, 000	7, 585, 000	142, 396	131, 016
Mississippi	6, 017, 600	6, 052, 000	143, 669	137, 983
Arkansas	5, 533, 000	5, 500, 000	106, 155	107, 203
Louisiana	3, 658, 100	3, 767, 200	87, 519	92, 500
Oklahoma	12, 475, 000	12, 889, 000	101, 335	122, 221
Texas	26, 870, 000	27, 554, 000	330, 127	375, 298
South Central	72, 285, 700	73, 352, 500	1, 154, 464	1, 174, 443
Montana	5, 183, 100	6, 508, 600	56, 701	64, 400
Idaho	2, 586, 000	2, 723, 000	58, 166	57, 403
Wyoming	1, 353, 000	1, 932, 000	17, 093	22, 230
Colorado	3, 800, 000	5, 216, 000	49, 516	62, 894
New Mexico	918, 200	1, 321, 100	18, 031	18, 999
Arizona	493, 000	533, 000	24, 350	26, 563
Utah	930, 000	1, 077, 600	16, 265	21, 727
Nevada	270, 000	336, 000	2, 746	3, 594
Washington	3, 165, 900	3, 310, 000	87, 254	86, 787
Oregon	2, 612, 000	2, 711, 000	49, 268	50, 323
California	4, 917, 000	5, 372, 000	368, 356	367, 143
Western	26, 228, 200	31, 040, 300	747, 746	782, 063
United States	286, 512, 600	327, 660, 900	4, 779, 335	5, 118, 444

[1] Includes corn (all), wheat (all), oats, barley, rye, buckwheat, flaxseed, rice, grain sorghums (all), cotton, tame hay (all), wild hay, sweet sorgo for forage and hay, timothy seed, red and alsike clover seed, sweetclover seed, lespedeza seed, alfalfa seed, dry edible beans, soybeans for beans, cowpeas for peas, peanuts for nuts, velvetbeans (total), sorgo for sirup, sugarcane, sugar beets, potatoes, sweetpotatoes, tobacco, broomcorn, asparagus, snap beans, cabbage, cantaloups, cauliflower, celery, sweet corn, cucumbers, lettuce, onions, green peas, spinach, tomatoes, and watermelons=44 crops. Farm value includes, in addition to the above, apples (total), peaches, pears, grapes, cherries, cranberries, oranges, grapefruit, lemons (California), limes (Florida), plums (2 States), prunes (all), apricots (California), figs (California), olives (California), almonds (California), walnuts (2 States), pecans, maple products, and hops=64 crops.

[2] Preliminary.

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TABLE 3.—*Gross income [1] from farm production, United States, by commodities, 1932–34*

Product	Gross income [2]		
	1932	1933	1934 [3]
	1,000 dollars	*1,000 dollars*	*1,000 dollars*
CROPS			
Corn	171, 404	215, 252	137, 279
Wheat	203, 117	288, 073	303, 284
Oats	34, 808	36, 317	30, 296
Barley	16, 895	19, 607	26, 945
Rye	4, 130	4, 336	3, 077
Buckwheat	2, 016	3, 219	4, 143
Flaxseed	9, 464	9, 966	7, 605
Rice	16, 489	27, 403	28, 299
Grain sorghums	2, 566	6, 257	1, 899
Emmer and spelt	86	73	66
Popcorn	863	501	589
Cotton lint	424, 006	634, 396	612, 802
Cottonseed	40, 323	53, 854	110, 040
Tobacco	107, 821	179, 486	240, 937
Hay	53, 232	65, 311	85, 898
Sweet sorgo for forage	1, 348	2, 281	2, 690
Hemp	5	6	21
Clover seed (red and alsike)	7, 289	7, 616	9, 198
Sweetclover seed	707	1, 098	1, 647
Lespedeza seed	2, 145	2, 928	2, 878
Alfalfa seed	3, 028	5, 729	7, 302
Timothy seed	1, 219	1, 434	1, 047
Dry edible beans	18, 126	29, 938	31, 136
Soybeans	4, 870	7, 669	14, 827
Cowpeas	3, 115	4, 802	5, 308
Peanuts	13, 486	21, 710	30, 569
Broomcorn	1, 381	3, 153	5, 462
Potatoes	116, 225	222, 364	162, 617
Sweetpotatoes	35, 090	40, 092	46, 616
Truck crops	222, 714	230, 772	259, 038
Hops	4, 199	12, 147	5, 779
Apples	86, 638	111, 799	109, 426
Peaches	18, 838	32, 340	34, 770
Pears	7, 627	10, 780	16, 193
Cherries	5, 157	6, 575	6, 791
Plums and apricots	2, 773	4, 088	3, 834
Grapes	26, 982	33, 841	35, 519
Other fruits and nuts	111, 776	144, 282	175, 239
Strawberries	32, 488	27, 870	31, 547
Small fruits	10, 636	9, 525	10, 782
Cranberries	4, 169	3, 950	4, 627
Pecans	2, 998	4, 749	5, 004
Sugar beets for sugar	47, 705	56, 599	38, 463
Sugarcane and sirup	13, 657	15, 078	14, 145
Sorghum sirup	3, 898	4, 862	4, 801
Maple sugar and sirup	4, 049	2, 847	3, 506
Forest products	105, 427	114, 784	116, 728
Farm gardens	214, 650	219, 090	195, 402
Nursery products	31, 095	39, 305	40, 838
Greenhouse products	44, 245	56, 062	57, 268
Total crops [4]	2, 296, 975	3, 036, 216	3, 084, 177

Product	Gross income [2]		
	1932	1933	1934 [3]
LIVESTOCK AND LIVESTOCK PRODUCTS	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*
Cattle and calves	498, 634	475, 835	717, 403
Hogs	548, 374	616, 612	613, 173
Sheep and lambs	76, 044	77, 078	106, 517
Horses	7, 785	8, 387	11, 900
Mules	3, 648	6, 317	6, 681
Chickens	240, 929	207, 402	236, 718
Eggs (chicken)	358, 982	345, 018	417, 214
Milk	1, 260, 424	1, 262, 554	1, 421, 253
Wool	30, 014	75, 031	77, 522
Mohair	1, 485	4, 753	2, 354
Total livestock	3, 026, 319	3, 078, 987	3, 610, 735
Total crops and livestock	5, 323, 294	6, 115, 203	6, 694, 912
BENEFIT PAYMENTS [5]			
Corn			111, 837
Wheat		98, 600	101, 508
Cotton lint		173, 676	115, 824
Tobacco		5, 772	36, 276
Sugar beets for sugar			[4] 18, 459
Sugarcane and sirup			6, 500
Cattle and calves			[6] 106, 165
Hogs		[6] 30, 643	203, 694
Sheep and lambs			[6] 7, 206
Total crops, livestock, and benefit payments	5, 323, 294	6, 393, 251	7, 289, 010
United States: After deducting for interstate sales of crops, principally seeds, and adding for "other poultry" and honey not estimated by States. Gross income plus benefit payments	5, 336, 858	6, 405, 702	7, 300, 406

[1] Estimated quantities produced, sold, and consumed in farm households times weighted annual prices. Cash income plus value of commodities consumed in farm households equals gross incomes. For feed and seed crops, horses, and mules, value includes sales by farmers in some States eventually bought by farmers in other States. These interfarm sales tend to overestimate the total income from farm production for the country as a whole.

[2] Weighted average price paid to producers for crop-marketing season used in evaluating commodities, except for 1934, for which prices through December were used, weighted by usual marketing rates and with allowance for usual departure from weighted season price for marketing season.

[3] Preliminary.

[4] United States totals include sugar beets for "Other States"; 1932—$4,456,000; 1933—$5,229,000; 1934—$2,827,000. 1934 also includes $1,523,000 benefit payments for other States.

[5] Gross payments. County administrative expenses not deducted for wheat, corn, hogs, sugar beets, sugarcane, and sirup.

[6] These Government purchases are included in gross income above.

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TABLE 4.—*Gross income [1] from farm production, by States, 1932–34*

State	Crops			Livestock and livestock products			Crops and livestock products combined [2]		
	1932	1933	1934 [3]	1932	1933	1934 [3]	1932	1933	1934 [3]
	1,000 dollars	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*
Maine	18, 572	35, 807	20, 757	22, 046	20, 343	22, 152	40, 618	56, 150	42, 914
New Hampshire	4, 646	5, 700	4, 837	12, 941	12, 161	13, 698	17, 587	17, 864	18, 586
Vermont	7, 528	7, 624	7, 478	25, 394	25, 139	27, 139	32, 922	32, 766	34, 704
Massachusetts	20, 011	26, 354	23, 050	31, 284	28, 596	32, 178	51, 295	55, 085	56, 159
Rhode Island	1, 854	2, 719	2, 166	4, 876	4, 660	5, 320	6, 730	7, 379	7, 491
Connecticut	13, 213	15, 767	13, 797	25, 044	24, 416	27, 959	38, 257	40, 468	42, 884
New York	72, 711	97, 925	86, 241	150, 759	153, 637	176, 579	223, 470	251, 637	263, 262
New Jersey	35, 562	41, 023	36, 226	34, 322	33, 937	41, 676	69, 884	74, 971	78, 324
Pennsylvania	55, 719	78, 907	76, 836	135, 826	135, 278	161, 197	191, 545	215, 002	240, 067
Ohio	56, 905	79, 430	86, 275	134, 767	143, 727	163, 150	191, 672	225, 290	270, 836
Indiana	43, 225	52, 172	65, 312	117, 801	125, 254	140, 254	161, 026	179, 310	233, 184
Illinois	97, 890	104, 819	97, 772	173, 915	186, 969	210, 885	271, 805	294, 280	351, 580
Michigan	54, 390	71, 812	72, 731	87, 929	88, 737	103, 593	142, 319	161, 377	182, 701
Wisconsin	25, 417	37, 697	47, 090	158, 788	165, 875	182, 882	184, 205	204, 135	239, 306
Minnesota	45, 350	63, 313	57, 672	149, 908	152, 037	176, 829	195, 258	217, 232	257, 730
Iowa	60, 056	95, 491	42, 544	251, 148	250, 080	312, 849	311, 204	346, 002	429, 785
Missouri	47, 357	61, 125	54, 602	139, 043	147, 209	161, 648	186, 400	212, 388	245, 515
North Dakota	40, 051	50, 177	16, 491	38, 020	41, 320	52, 464	78, 071	106, 174	87, 027
South Dakota	23, 821	7, 596	2, 906	52, 570	67, 731	70, 627	76, 391	80, 454	92, 969
Nebraska	42, 832	62, 446	21, 082	123, 862	122, 190	173, 463	166, 694	190, 580	232, 777
Kansas	51, 299	54, 184	61, 806	116, 873	114, 860	142, 306	168, 172	193, 447	245, 983
Delaware	5, 255	6, 262	8, 549	6, 874	6, 333	7, 192	12, 129	12, 705	15, 891
Maryland	21, 508	27, 045	31, 885	29, 484	27, 977	32, 778	50, 992	55, 818	66, 137
Virginia	46, 853	68, 382	82, 067	54, 288	50, 015	57, 389	101, 141	119, 181	143, 715
West Virginia	15, 092	18, 617	18, 517	29, 592	28, 963	32, 867	44, 684	47, 656	51, 965
North Carolina	104, 456	182, 760	234, 911	45, 625	44, 445	51, 372	150, 081	233, 946	303, 236
South Carolina	50, 973	73, 789	87, 283	22, 345	22, 088	23, 611	73, 318	106, 245	120, 139
Georgia	66, 693	108, 922	131, 356	38, 787	36, 240	41, 567	105, 480	159, 703	184, 499
Florida	65, 934	71, 528	79, 804	16, 520	16, 410	17, 402	82, 454	88, 454	98, 031
Kentucky	58, 782	68, 458	82, 258	54, 853	55, 217	61, 521	113, 635	123, 996	159, 798
Tennessee	58, 662	79, 454	90, 937	46, 674	47, 006	50, 641	105, 336	131, 585	152, 241
Alabama	67, 199	88, 159	114, 963	34, 007	34, 386	36, 208	101, 206	137, 095	161, 956
Mississippi	72, 372	92, 953	120, 270	29, 873	28, 231	33, 352	102, 245	138, 495	166, 440
Arkansas	70, 927	84, 271	91, 953	29, 461	28, 926	33, 097	100, 388	130, 196	137, 547
Louisiana	57, 512	65, 989	78, 477	23, 582	22, 284	24, 419	81, 094	96, 180	115, 794
Oklahoma	65, 650	96, 855	63, 895	57, 674	61, 231	66, 470	123, 324	181, 750	150, 971
Texas	227, 383	296, 494	253, 561	132, 469	147, 221	170, 580	359, 852	511, 341	469, 272
Montana	25, 601	24, 885	34, 722	29, 493	33, 729	48, 156	55, 094	64, 945	91, 562
Idaho	22, 903	34, 572	35, 000	24, 161	26, 538	32, 375	47, 064	64, 509	73, 365
Wyoming	5, 743	8, 806	6, 431	18, 427	19, 926	30, 844	24, 170	29, 139	39, 281
Colorado	23, 343	38, 870	25, 595	41, 607	33, 913	51, 498	64, 950	74, 925	86, 344
New Mexico	7, 509	11, 839	12, 849	17, 324	17, 348	26, 771	24, 833	30, 378	41, 318
Arizona	11, 079	15, 137	19, 636	13, 686	14, 303	15, 413	24, 765	30, 083	36, 133
Utah	10, 444	12, 034	8, 661	17, 964	18, 388	20, 758	28, 408	31, 082	31, 498
Nevada	810	882	896	5, 584	5, 929	7, 013	6, 394	6, 841	8, 006
Washington	48, 952	70, 931	80, 051	44, 114	44, 473	50, 908	93, 066	121, 206	137, 626
Oregon	29, 735	40, 404	40, 760	35, 327	34, 819	42, 552	65, 062	77, 885	86, 923
California	232, 740	290, 601	348, 392	139, 408	128, 492	145, 133	372, 148	420, 692	501, 188
United States	[4] 2,296,975	[4] 3,036,216	[4] 3,084,177	3, 026, 319	3, 078, 987	3, 610, 735	[4] 5,323,294	[4] 6,393,251	[4] 7,289,010

[1] Estimated quantities produced, sold, and consumed in farm households times weighted annual prices. Cash income plus value of commodities consumed in farm households equals gross incomes. For feed and seed crops, horses, and mules, value includes sales by farmers in some States eventually bought by farmers in other States. These interfarm sales tend to overestimate the total income from farm production for the country as a whole.

[2] Includes benefit payments shown in table 3.

[3] Preliminary.

[4] United States totals include sugar beets for "Other States", 1932—$4,456,000; 1933—$5,229,000; 1934—$2,827,000 and $1,523,000 benefit payments.

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TABLE 5.—*Gross income from farm production and rental and benefit payments by groups of commodities, expenditures, income available for operators' capital, labor, and management and current value of capital employed in agriculture, United States, 1925–34*

Item	1925	1926	1927	1928	1929 [1]	1930 [1]	1931 [1]	1932 [1]	1933 [1]	1934 [1]
	Million dol.	*Million dol.*	*Million dol.*	*Million dol.*	*Million dol.*	*Million dol.*	*Million dol.*	*Million dol.*	*Million dol.*	*Million dol.*
Crops:										
Grains	1,496	1,432	1,592	1,513	1,297	806	488	452	601	536
Fruits and nuts	683	694	690	705	707	567	457	324	412	464
Vegetables	1,193	1,093	1,062	967	1,130	934	726	611	754	701
Sugar crops	95	103	104	92	83	94	69	69	79	61
Cotton and cottonseed	1,740	1,251	1,464	1,470	1,389	751	528	464	688	706
Tobacco	251	237	257	278	286	212	130	108	179	224
Other crops	690	658	648	650	542	454	348	269	319	351
Total crops	6,148	5,468	5,817	5,675	5,434	3,818	2,746	2,285	3,032	3,043
Livestock and livestock products:										
Cattle, hogs, and sheep	2,822	2,922	2,664	2,727	2,805	2,448	1,719	1,123	1,170	1,436
Poultry and eggs	1,114	1,167	1,108	1,202	1,241	1,059	816	609	561	664
Dairy products	1,759	1,805	1,911	1,994	2,323	2,031	1,614	1,260	1,263	1,421
Wool	97	88	86	111	99	68	50	30	75	78
Other	28	30	30	32	39	30	23	20	27	30
Total livestock	5,820	6,012	5,799	6,066	6,507	5,636	4,222	3,042	3,096	3,629
Total crops and livestock	11,968	11,480	11,616	11,741	11,941	9,454	6,968	5,337	6,128	6,672
Rental and benefit payments:										
Corn										112
Wheat									98	102
Cotton									174	116
Tobacco									6	36
Sugar beets										18
Sugarcane										6
Hogs										204
Total									278	594
Grand total									6,406	7,266
Expenditures:										
Current expenditures for production [2]	1,724	1,816	1,775	1,896	1,958	1,722	1,339	1,120	1,147	1,206
Depreciation of buildings and equipment [3]	896	889	894	894	912	892	843	805	762	789
Wages, interest, rent, and taxes [4]	3,194	3,237	3,294	3,339	3,392	2,975	2,378	1,915	1,804	1,814
Total deductions	5,814	5,942	5,963	6,129	6,262	5,589	4,560	3,840	3,713	3,809
Income available for operators' labor, capital, and management	6,154	5,538	5,653	5,612	5,679	3,865	2,408	1,497	2,693	3,457
Amount available for capital and management [5]	1,707	1,004	1,152	1,121	1,160	−231	−810	−963	396	871
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Return to capital and management as percentage of operators' net capital	5.1	3.0	3.5	3.4	3.4	−0.7	−2.7	−4.1	2.1	4.3

[1] Estimates since 1929 have been adjusted to the revised estimates of production which were made after the 1930 census data became available. Estimates of income from 1924–28 have not yet been adjusted to revised production estimates. The 1929 estimate of income from crops, comparable with the estimates of 1924–28, was $5,609,000,000 and 1929 estimate of livestock was $6,302,000,000: total gross income on the old base for 1929 was $11,950,000,000.

[2] All of the current operating costs except 7.5 percent of fertilizer costs, 9.5 percent of feed, 10 percent of binder twine, 15 percent of ginning costs and 20 percent of fire-insurance costs which are estimated as paid by nonfarmer landlords.

[3] Depreciation of farm buildings and farm equipment is based upon the value of buildings and farm equipment according to the 1919 and 1929 census, the amount spent for replacements on buildings and machinery and price changes for farm machinery and building materials. While the rate of depreciation fluctuates slightly from year to year, during the last 14 years it has averaged about 5 percent of the value of farm buildings and 21 percent of the value of machinery, automobiles, and trucks.

[4] Cash wages to hired labor plus an allowance of 25 percent for board and an additional 12½ percent of the cash wage to represent perquisites furnished hired labor and domestic hired labor contributing to production. Includes only that portion of interest payable by farm operators: figured at 75 percent of all interest payable on farm-mortgage debt on real estate used in production and interest on all bank loans, other than real estate loans. It is assumed that 70 percent of all taxes on farm property used in production are paid by farm operators and that 72 percent of all rent paid is paid to nonfarmer landlords.

[5] Allowing a return for labor of the farm operator and unpaid family labor at a wage rate equal to that of hired labor without board.

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Table 6.—*Current value of agricultural capital, gross income from farm production, and selected expenditures, United States, 1909–34*

Year	Current value of agricultural capital [1]	Gross income from farm production [2]	Selected expenditures: Wages (including board) [3]	Feed [4]	Fertilizer [5]	Farm implements (including autos and trucks) [6]	Cost of operating autos, trucks, and tractors [7]	Ginning [8]	Taxes on farm real estate [9]	Interest on farm mortgages [10]
	Million dollars	*Million dollars*	*Million dollars*	*Million dollars*	*Million dollars*	*Million dollars*	*Million dollars*	*Million dollars*	*Million dollars*	*Million dollars*
1909	41, 354	6, 238	652	300	115	222	2	33	200	-------
1910	42, 985	6, 643	674	302	137	239	4	39	204	199
1911	44, 086	6, 372	673	372	152	237	8	52	210	210
1912	46, 081	6, 784	697	336	153	256	15	45	212	221
1913	47, 778	6, 975	721	453	172	270	24	46	218	232
1914	47, 965	7, 028	696	431	188	284	44	56	222	240
1915	50, 533	7, 395	701	471	158	315	67	43	243	252
1916	55, 041	8, 914	766	638	163	394	116	50	260	269
1917	61, 576	12, 832	941	871	217	509	181	54	292	299
1918	67, 055	15, 101	1, 162	1, 023	297	569	246	64	311	345
1919	66, 630	16, 935	1, 363	1, 097	328	651	380	77	393	401
1920	78, 436	13, 566	1, 636	1, 028	350	742	410	91	483	479
1921	71, 146	8, 927	1, 017	958	199	359	324	47	510	545
1922	62, 022	9, 944	981	888	192	433	206	59	509	554
1923	60, 356	11, 041	1, 102	819	213	618	299	61	516	568
1924	58, 244	11, 337	1, 074	750	215	568	321	82	511	564
1925	57, 189	11, 968	1, 118	784	248	725	375	100	517	567
1926	57, 255	11, 480	1, 161	818	242	671	417	117	526	568
1927	56, 145	11, 616	1, 175	851	217	654	422	73	545	568
1928	56, 561	11, 741	1, 183	885	275	801	443	88	556	568
1929	57, 604	11, 941	1, 194	919	276	916	472	89	567	563
1930	57, 670	9, 454	1, 011	685	270	677	468	77	566	554
1931	51, 812	6, 968	734	462	190	366	390	75	519	545
1932	43, 351	5, 337	475	409	113	186	362	56	450	528
1933	35, 816	6, 406	440	427	122	218	365	63	387	511
1934 [11]	37, 050	7, 266	471	424	150	375	397	51	365	442

[1] As of Jan. 1. Includes land, buildings, machinery, and livestock. Estimates are census values for census years. The value of land and buildings for intercensal years is based on the index of land values per acre and a straight-line interpolation of total acreage in farms. Livestock values are annual estimates of the U. S. Department of Agriculture. Value of farm machinery is based on estimated purchases of farm machinery and changes in the prices paid by farmers for farm machinery.

[2] For more detailed information for the years 1925–34, see table 5. The estimates for 1909–23 are based on items which represent about 95 percent of the gross income in 1924–34.

[3] Estimates from 1909–24 based on interpolations between census estimates and the index of farm wage rates; 1924–33 upon farm-wage rate, changes in the number of hired laborers per farm, and the number of farms.

[4] From 1909 to 1919 interpolation between census years based on an index of prices paid by farmers for feed and an index of production of feed crops. From 1919 to 1933 estimates are based on prices of feed crops, production of byproducts feeds and sales of feed grains and hay which are not used in industry or exported.

[5] Interpolated between census estimates based on estimated total fertilizer consumption and the U. S. Department of Agriculture index of fertilizer prices paid by farmers.

[6] Value of farm implements interpolated between the 1909, 1914, and 1919 census value of implements produced, after adjustment to represent retail values. Interpolations for other years are based on factory values of farm implements sold in the United States and raised to retail values. Farmers' expenditures for automobiles and trucks are estimated from registrations in principal agricultural States and prices paid by farmers.

[7] Includes the estimated cost of operating trucks, tractors, and one-half of the cost of operating automobiles. Expenditures per vehicle are based upon changes in the prices of gasoline, kerosene, oil and tires, licenses, and estimated annual mileage. Cost of operation is estimated cost per vehicle times estimated number of vehicles on farms.

[8] Annual cotton production multiplied by ginning costs per bale.

[9] Estimates of taxes are based on a study of real-estate taxes by States. For additional information on taxes paid by farmers see House Document No. 406, The Farmers' Tax Problem.

[10] On mortgage indebtedness as of Jan. 1. Estimates for 1910, 1920, 1925, 1928, 1930, and 1933 based on census data or special farm-mortgage studies. Interpolations for intervening years were made from smooth curve fitted to above mentioned years and from changes in the current value of agricultural capital.

[11] Preliminary.

Bureau of Agricultural Economics; tentative estimates of the Bureau.

TABLE 7.—*Index numbers of prices paid by farmers, 1910–35*

[Calendar years 1910–14=100]

Year	Commodities used in production: Feed	Machinery	Fertilizer	Building materials for other than house	Equipment and supplies	Seed [1]	All commodities bought for use in production	Wage rates paid to hired labor	Commodities bought for use in production plus wages paid to hired labor	Commodities bought for family maintenance [2]	All commodities bought for use in production and family maintenance
1910	93	102	99	100	101	------	98	97	98	98	98
1911	107	101	99	102	100	------	103	97	101	100	101
1912	91	102	100	103	100	103	98	101	99	101	100
1913	107	98	102	101	100	97	102	104	103	100	101
1914	102	96	100	93	99	99	99	101	99	102	100
1915	100	100	112	102	106	120	104	102	103	107	105
1916	130	107	120	117	129	142	124	112	121	124	124
1917	184	126	137	137	156	149	151	140	149	147	149
1918	193	155	170	161	181	190	174	176	174	177	176
1919	211	161	182	189	180	280	192	206	195	210	202
1920	137	167	186	205	189	152	174	239	189	222	201
1921	97	156	156	156	152	134	141	150	143	161	152
1922	123	142	129	159	140	130	139	146	141	156	149
1923	134	146	126	161	136	142	141	166	147	160	152
1924	142	152	120	161	133	151	143	166	148	159	152
1925	141	153	129	164	140	172	147	168	152	164	157
1926	137	154	126	162	144	214	146	171	152	162	155
1927	138	154	121	160	141	197	145	170	151	159	153
1928	148	154	131	158	138	179	148	169	153	160	155
1929	145	153	130	159	136	185	147	170	153	158	153
1930	132	152	126	155	131	174	140	152	143	148	145
1931	93	150	115	139	116	152	122	116	120	126	124
1932	69	141	99	126	107	102	107	86	102	108	107
1933	79	137	96	129	103	95	108	80	101	109	109
1934	110	144	104	146	109	140	125	90	117	122	123
1935	111	148	102	145	108	154	126	98	119	124	125

[1] 1912–14=100.

[2] Includes food, clothing, household operating expenses, furniture and furnishings, and building materials for house.

Bureau of Agricultural Economics; compiled from prices reported to the Department of Agriculture by retail dealers throughout the United States. The prices used in constructing the above index numbers of prices paid by farmers are for constant quantities and sizes, but are not adjusted for changes in quality. Over a period of years marked changes may occur in the quality of certain commodities. For example, a study by the American Society of Agricultural Engineers indicated an improvement in quality of farm machinery of about 70 percent between 1910–14 and 1932.

The index numbers include only commodities bought by farmers; the commodities being weighted according to purchases reported by actual farmers in farm-management and rural-life studies from 1920 to 1925.

TABLE 8.—*Index numbers of farm prices, by groups, 1910–35*

[August 1909–July 1914=100]

Year	Calendar year							Year beginning July 1 of year shown						
	Grains	Cotton and cottonseed	Fruits	Dairy products	Chickens and eggs	Meat animals	All groups	Grains	Cotton and cottonseed	Fruits	Dairy products	Chickens and eggs	Meat animals	All groups
1910	104	113	101	99	104	103	102	95	114	103	96	95	94	98
1911	96	101	102	95	91	87	95	107	84	100	100	97	88	98
1912	106	87	94	102	100	95	100	93	93	95	104	97	104	98
1913	92	97	107	105	101	108	101	97	99	109	103	107	111	104
1914	102	85	91	102	106	112	101	120	69	74	104	103	108	98
1915	120	77	82	103	101	104	98	109	94	90	104	104	110	103
1916	126	119	100	109	116	120	118	172	148	111	120	137	143	146
1917	217	187	118	135	155	174	175	230	229	146	148	168	193	192
1918	227	245	172	163	186	203	202	227	233	179	175	197	211	206
1919	233	247	178	186	209	207	213	248	285	198	196	219	191	228
1920	232	248	191	198	223	174	211	165	140	151	178	193	140	157
1921	112	101	157	156	162	109	125	103	129	188	144	151	108	128
1922	106	156	174	143	141	114	132	110	194	147	152	144	111	138
1923	113	216	137	159	146	107	142	112	225	121	158	144	105	142
1924	129	212	125	149	149	110	143	156	189	153	145	160	126	149
1925	157	177	172	153	163	140	156	142	151	163	154	160	146	154
1926	131	122	138	152	159	147	145	125	106	121	154	152	143	136
1927	128	128	144	155	144	140	139	135	154	182	155	148	142	147
1928	130	152	176	158	153	151	149	118	150	142	159	158	158	146
1929	120	144	141	157	162	156	146	117	130	168	147	154	150	143
1930	100	102	162	137	129	133	126	82	79	126	122	109	112	104
1931	63	63	98	108	100	92	87	52	48	86	96	89	73	73
1932	44	47	82	83	82	63	65	43	51	75	78	80	60	62
1933	62	64	74	82	75	60	70	79	83	88	90	80	62	81
1934	93	99	100	95	89	68	90	109	106	96	106	106	92	103
1935	103	101	91	108	117	118	108	-----	-----	-----	-----	-----	-----	-----

Bureau of Agricultural Economics.

TABLE 9.—*Farm-wage rates: Averages and index numbers, 1909–35*

Year	Average yearly farm wage [1]				Weighted average wage rate per month [2]	Index numbers of farm wages [3]	Year	Average yearly farm wage [1]				Weighted average wage rate per month [2]	Index numbers of farm wages [3]
	Per month—		Per day—					Per month—		Per day—			
	With board	Without board	With board	Without board				With board	Without board	With board	Without board		
	Dol.	*Dol.*	*Dol.*	*Dol.*	*Dol.*			*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	
1909	20.48	28.09	1.04	1.31	23.00	96	1923	33.09	46.74	1.91	2.45	39.64	166
1910	19.58	28.04	1.07	1.40	23.08	97	1924 [4]	33.34	47.22	1.88	2.44	39.67	166
1911	19.85	28.33	1.07	1.40	23.25	97	1925 [4]	33.88	47.80	1.89	2.46	40.12	168
1912	20.46	29.14	1.12	1.44	24.01	101	1926 [4]	34.86	48.86	1.91	2.48	40.88	171
1913	21.27	30.21	1.15	1.48	24.83	104	1927 [4]	34.58	48.63	1.90	2.46	40.60	170
1914	20.90	29.72	1.11	1.44	24.26	101	1928 [4]	34.66	48.65	1.88	2.43	40.44	169
1915	21.08	29.97	1.12	1.45	24.46	102	1929 [4]	34.74	49.08	1.88	2.42	40.52	170
1916	23.04	32.58	1.24	1.60	26.83	112	1930 [4]	31.14	44.59	1.65	2.16	36.24	152
1917	28.64	40.19	1.56	2.00	33.42	140	1931 [4]	23.60	35.03	1.22	1.65	27.61	116
1918	35.12	49.13	2.05	2.61	42.12	176	1932 [4]	17.53	26.67	.88	1.21	20.46	86
1919	40.14	56.77	2.44	3.10	49.11	206	1933 [4]	15.86	24.51	.86	1.18	19.17	80
1920	47.24	65.05	2.84	3.56	57.01	239	1934 [4]	17.89	27.17	.98	1.31	21.50	90
1921	30.25	43.58	1.66	2.17	35.77	150	1935 [4]	19.66	29.48	1.06	1.43	23.45	98
1922	29.31	42.09	1.64	2.14	34.91	146							

[1] Yearly averages are from reports by crop reporters, giving average wages for the year in their localities.
[2] This column has significance only as an essential step in computing the wage index.
[3] Calendar years 1910–14=100.
[4] Weighted average of quarterly reports, April (weight 1), July (weight 5), October (weight 5), and January of the following year (weight 1).

Bureau of Agricultural Economics. Data for earlier years in 1928 Yearbook, table 531.

TABLE 10.—*Index numbers of wholesale prices, by groups of commodities, United States, 1910–35* [1]

[Calendar years 1910–14=100]

Year	Farm products	Foods	Hides and leather products	Textile products	Fuel and lighting	Metals and metal products	Building materials	Chemicals and drugs	House furnishing goods	Miscellaneous	All commodities
1910	104	101	93	104	90	100	100	101	99	139	103
1911	94	96	91	99	89	95	100	100	96	99	95
1912	102	104	100	99	98	105	101	99	97	97	101
1913	100	100	106	102	116	106	103	99	103	85	102
1914	100	100	110	97	107	94	96	100	104	82	99
1915	100	101	117	96	98	101	97	138	103	79	102
1916	118	117	145	125	141	137	122	198	112	91	125
1917	181	162	192	175	200	177	160	203	136	111	172
1918	208	185	195	244	207	160	179	224	171	122	192
1919	221	201	270	240	198	154	209	193	194	126	202
1920	211	213	266	293	311	175	272	203	260	152	225
1921	124	140	169	168	184	138	176	142	207	99	142
1922	132	136	162	178	204	121	176	124	190	84	141
1923	138	144	162	198	185	128	197	124	200	91	147
1924	140	141	157	190	175	125	185	122	192	85	143
1925	154	155	163	192	183	121	184	125	189	99	151
1926	140	155	155	178	190	117	181	123	183	91	146
1927	139	150	167	170	168	113	172	119	179	83	139
1928	148	157	188	170	160	114	170	118	174	78	141
1929	147	155	169	161	158	118	173	116	173	75	139
1930	124	140	155	143	149	108	163	110	170	71	126
1931	91	116	134	118	128	99	144	98	156	63	107
1932	68	95	113	98	133	94	129	90	138	58	95
1933	72	94	125	115	126	94	140	89	139	57	96
1934	92	109	134	130	139	102	156	94	149	63	109
1935	111	130	139	126	139	101	155	99	148	62	117

[1] Computed by reducing to a 1910–14 base the Bureau of Labor Statistics series, 1926=100; the index numbers for each group on the 1926 base are divided by the monthly averages for 1910–14. The averages used for each group are as follows: Farm products, 71.3; foods, 64.5; hides and leather products, 64.5; textile products, 56.3; fuel and lighting, 52.7; metals and metal products, 85.3; building materials, 55.2; chemicals and drugs, 81.2; house furnishing goods, 54.6; miscellaneous, 110.1; and all commodities, 68.5.

Bureau of Agricultural Economics.

TABLE 11.—*Farm real estate: Index numbers of estimated value per acre, by geographic divisions, 1912–36* [1]

[1912–14=100]

Year	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South-Central	West South Central	Mountain	Pacific	United States
1912	99	98	97	97	98	97	96	98	94	97
1913	101	100	100	100	100	100	100	102	99	100
1914	100	102	103	103	103	103	104	100	106	103
1915	99	100	104	105	98	99	100	98	107	103
1916	102	104	110	114	108	109	103	98	111	108
1917	112	112	116	122	119	120	116	106	122	117
1918	117	117	127	134	135	140	134	117	129	129
1919	123	121	135	147	161	162	143	130	134	140
1920	140	136	161	184	198	199	177	151	156	170
1921	135	127	151	174	174	163	159	133	155	157
1922	134	118	132	150	146	149	136	122	151	139
1923	130	116	128	142	152	149	132	115	148	135
1924	128	114	121	132	151	142	136	110	147	130
1925	127	114	116	126	148	141	144	105	146	127
1926	128	113	111	121	149	139	144	103	144	124
1927	127	111	104	115	137	133	139	101	143	119
1928	127	110	101	113	134	130	137	101	142	117
1929	126	109	100	112	132	129	136	101	142	116
1930	127	106	96	109	128	128	136	102	142	115
1931	126	101	87	97	116	117	121	100	140	106
1932	116	96	73	81	96	97	97	82	118	89
1933	105	82	62	64	80	79	82	69	96	73
1934	104	[2] 83	65	67	[2] 87	85	88	69	97	76
1935	104	[2] 85	68	68	[2] 93	93	91	70	101	79
1936	105	88	72	71	97	96	94	73	105	82

[1] All farm land with improvements, as of Mar. 1. Owing to rounding of figures, 1912–14 will not always equal exactly 100 percent.

[2] Revised.

Bureau of Agricultural Economics; based on values as reported by crop reporters.
Values as reported by the census for 1910, 1920, and 1925 will be found in 1927 Yearbook, table 511.
For details by States since 1912, refer to The Farm Real-Estate Situation, 1934–35, U. S. Department of Agriculture, Circular 382.

Table 12.—*Farm real estate taxes per acre, by geographic divisions, 1913–34*

Year	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	United States
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1913	0.41	0.49	0.52	0.24	0.14	0.14	0.11	0.10	0.33	0.24
1914	.43	.50	.51	.25	.15	.15	.11	.10	.35	.24
1915	.44	.54	.57	.27	.16	.15	.13	.10	.36	.26
1916	.46	.56	.64	.28	.17	.17	.13	.10	.39	.28
1917	.51	.62	.69	.32	.19	.19	.15	.12	.43	.31
1918	.53	.66	.71	.34	.22	.22	.17	.12	.44	.33
1919	.62	.73	.89	.45	.26	.26	.22	.17	.55	.41
1920	.74	.89	1.10	.54	.33	.36	.24	.20	.73	.51
1921	.77	.94	1.18	.59	.36	.38	.25	.20	.74	.54
1922	.81	.99	1.19	.57	.37	.39	.25	.19	.78	.54
1923	.85	1.05	1.19	.58	.40	.41	.26	.19	.78	.55
1924	.86	1.09	1.20	.57	.42	.42	.27	.18	.76	.55
1925	.90	1 13	1.21	.58	.46	.41	.27	.18	.78	.56
1926	.96	1.17	1.21	.58	.47	.42	.26	.19	.82	.56
1927	.98	1.19	1.25	.59	.47	.43	.27	.19	.83	.57
1928	.99	1.22	1.25	.60	.48	.44	.28	.19	.86	.58
1929	1.01	1.21	1.27	.61	.48	.45	.29	.20	.85	.58
1930	1.02	1.24	1.25	.61	.45	.45	.30	.19	.83	.57
1931	1.03	1.22	1.10	.56	.42	.42	.27	.18	.77	.53
1932	.98	1.15	.90	.47	.38	.38	.23	.17	.68	.46
1933	.91	[1] 1.04	.71	.42	.30	.37	.21	.15	.52	[1] .39
1934	.94	[1] 1.01	.65	.40	.29	.34	.20	.15	.49	[1] .37

[1] Figures included for New Jersey, preliminary.

Bureau of Agricultural Economics.
For details by States see 1935 Yearbook, table 478; and Agricultural Statistics, 1936, table 458.

Table 13.—*Preliminary summary of results of the 1935 cotton production-adjustment program of the Agricultural Adjustment Administration, by States* [1]

State	Contracts received	Adjusted average base acreage	Adjusted average production	Rented acres	Adjusted average yield per acre	Percentage of base acreage rented	Estimated payments on contracts received [2]		
							Rental	Parity	Total
	Number	*Acres*	*Pounds*	*Acres*	*Pounds*	*Percent*	*Dollars*	*Dollars*	*Dollars*
Ala.	156,013	3,441,397	616,117,642	1,151,972	179	33.5	7,217,105	3,080,588	10,297,693
Ariz.	2,193	176,127	60,367,182	54,372	343	30.9	652,736	301,836	954,572
Ark.	107,555	3,485,018	663,177,657	1,164,664	190	33.4	7,745,016	3,315,888	11,060,904
Calif.	3,732	239,984	115,804,338	72,168	482	30.1	1,217,474	579,022	1,796,496
Fla.	10,132	132,382	18,584,488	42,698	140	32.3	209,220	92,922	302,142
Ga.	136,707	3,327,935	612,880,025	1,115,747	184	33.5	7,185,411	3,064,400	10,249,811
Ill.	134	1,709	367,348	486	215	28.4	3,657	1,837	5,494
Kans.	54	1,776	255,430	554	144	31.2	2,792	1,277	4,069
Ky.	2,052	21,543	5,411,108	8,589	251	39.9	75,454	27,056	102,510
La.	68,556	1,932,305	369,506,180	624,977	191	32.3	4,177,971	1,847,531	6,025,502
Miss.	109,706	3,962,472	749,201,765	1,295,513	189	32.7	8,569,818	3,746,009	12,315,827
Mo.	12,135	420,397	121,608,242	138,973	289	33.1	1,405,712	608,041	2,013,753
N. Mex.	3,083	135,363	46,691,682	45,491	345	33.6	549,304	233,458	782,762
N. C.	97,026	1,485,674	368,063,770	502,372	248	33.8	4,360,589	1,840,319	6,200,908
Okla.	119,287	3,884,469	567,934,068	1,280,340	146	33.0	6,542,537	2,839,670	9,382,207
S. C.	86,542	1,996,212	425,480,240	648,655	213	32.5	4,835,723	2,127,401	6,963,124
Tenn.	48,131	1,083,991	230,675,648	360,410	213	33.2	2,686,857	1,153,378	3,840,235
Tex.	292,257	15,645,130	2,206,527,867	5,047,919	141	32.3	24,911,480	11,032,639	35,944,119
Va.	7,870	80,318	21,508,802	27,521	268	34.3	258,147	107,544	365,691
Total	1,263,165	41,454,202	7,200,163,482	13,583,421	174	32.8	82,607,003	36,000,816	118,607,819

[1] Based on contracts received through Jan. 15, 1936.
[2] Estimated payments on the 1,308,500 contracts expected to be received will approximate $123,000,000.

Agricultural Adjustment Administration.

TABLE 14.—*Wheat-adjustment program of the Agricultural Adjustment Administration, number of contracts and acreage under contract, base production of contract signers, and adjustment payments, by States, 1933–35*

State	Farms growing wheat in 1929 [1]	Contracts approved [2]	Acreage seeded by all growers 1930–32 [3]	Average acreage under contract	Base acreage of contract signers, average 1930–32 [4]	Base production of contract signers, average 1928–32 [5]	Estimated amount of adjustment payments [6] 1933	1934	1935
	Number	*Number*	*1,000 acres*	*Percent*	*1,000 acres*	*1,000 bushels*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*
Alabama			4						
Arizona	960	114	28	22	6	141	21	22	25
Arkansas	1,048	41	30	6	2	18	3	3	3
California	5,098	2,241	677	65	442	8,170	1,196	1,280	1,457
Colorado	18,856	11,863	1,755	84	1,467	14,316	2,142	2,242	2,552
Connecticut	51								
Delaware	4,127	686	94	39	37	711	110	111	127
Florida									
Georgia	10,064	31	52	7	4	55	8	9	10
Idaho	23,318	14,779	1,142	86	981	22,569	3,399	3,534	4,023
Illinois	66,836	23,982	1,971	51	1,002	17,242	2,492	2,700	3,074
Indiana	65,187	24,041	1,652	45	747	12,768	1,882	1,999	2,276
Iowa	18,998	3,700	369	39	144	3,226	431	505	575
Kansas	88,320	94,061	13,516	89	12,101	157,983	24,398	24,740	28,154
Kentucky	12,553	3,970	259	54	139	1,730	249	271	308
Louisiana	5								
Maine	554		2						
Maryland	19,378	7,741	439	66	290	5,308	796	831	946
Massachusetts	38								
Michigan	63,581	13,981	719	34	245	5,631	828	882	1,004
Minnesota	55,752	21,729	1,368	62	842	12,474	1,850	1,953	2,224
Mississippi	12								
Missouri	50,166	16,149	1,536	45	697	10,828	1,534	1,696	1,931
Montana	29,143	39,114	4,446	94	4,321	42,050	6,331	6,585	7,494
Nebraska	54,949	34,038	3,674	72	2,643	40,142	5,944	6,286	7,154
Nevada	858	303	15	57	9	207	30	32	37
New Hampshire	10								
New Jersey	4,836	192	51	7	4	78	11	12	14
New Mexico	6,922	1,684	480	81	386	3,290	497	515	587
New York	24,931	589	220	6	12	295	44	46	53
North Carolina	49,070	1,058	334	6	22	350	53	55	62
North Dakota	68,689	104,326	10,368	94	9,929	95,684	14,677	14,985	17,053
Ohio	97,387	23,854	1,745	35	613	11,214	1,718	1,756	1,999
Oklahoma	38,688	29,066	4,533	78	3,536	44,538	6,840	6,974	7,938
Oregon	15,657	7,078	1,027	82	847	17,290	2,662	2,708	3,082
Pennsylvania	84,496	3,418	955	9	90	1,673	254	262	298
Rhode Island	4								
South Carolina	14,063		57						
South Dakota	41,300	49,590	3,895	90	3,518	33,634	5,127	5,267	5,995
Tennessee	21,804	2,273	249	29	71	877	128	137	156
Texas	23,058	14,423	4,346	85	3,674	35,068	5,422	5,492	6,250
Utah	13,038	5,627	272	76	206	4,388	660	687	782
Vermont	170								
Virginia	59,390	7,648	601	35	210	3,641	539	570	649
Washington	14,690	11,490	2,471	78	1,938	37,276	5,802	5,837	6,644
West Virginia	9,999	972	113	28	32	508	76	80	91
Wisconsin	24,072	1,203	101	14	14	267	39	42	48
Wyoming	5,965	2,363	360	69	248	2,945	407	461	525
Total	1,208,091	579,418	65,926	78	51,469	648,585	98,600	101,600	115,600

[1] Bureau of the Census, 1930.
[2] From records of Division of Grains, A. A. A.
[3] Official estimates of the Bureau of Agricultural Economics.
[4] Some counties and individuals in numerous counties used 4-year and 5-year bases which are included in these figures. The estimated contracted acreages, or adjusted acreages, by States, for 1934 were 15 percent of these totals, and those for 1935 were 10 percent. There were no contracted acres in 1933.
[5] Base production on contracts adjusted to the 5-year base, 1928–32.
[6] Estimated payments at 29 cents per bushel on 54 percent of the base production for the 1933 and 1934 crops, and at 33 cents per bushel for the 1935 crop. Totals include local administrative costs.

Agricultural Adjustment Administration.

Table 15.—*Preliminary summary of results of 1935 corn-hog adjustment program of the Agricultural Adjustment Administration, by States*

[Statement to Jan. 28, 1936]

State and division	Contracts accepted for audit	Contract signers' base corn acreage, as adjusted	Acreage contracted for retirement [1]	Adjusted base acreage per contract	Acreage retired as percentage of base	Average appraised yield per acre of cornland	Contract signers' hog base, as adjusted [2]	Hog base per contract
	Number	*Acres*	*Acres*	*Acres*	*Percent*	*Bushels*	*Number*	*Number*
Maine	10	32		3.2			1,395	139.5
New Hampshire	111	354	3	3.2	0.8	55.0	9,236	83.2
Vermont	354	1,890	37	5.3	2.0	45.3	16,056	45.4
Massachusetts	193	312	2	1.6	.6	36.0	118,395	613.4
Rhode Island	7	1		.1			1,314	187.7
Connecticut	71	358	18	5.0	5.0	32.9	14,707	207.1
New York	1,324	10,481	614	7.9	5.9	35.3	73,671	55.6
New Jersey	255	3,975	949	15.6	23.9	39.0	96,763	379.5
Pennsylvania	2,530	58,346	13,516	23.1	23.2	41.8	94,281	37.3
North Atlantic	4,855	75,749	15,139	15.6	20.0	41.4	425,818	87.7
Ohio	45,208	1,546,900	303,508	34.2	19.6	36.5	2,499,993	55.3
Indiana	62,525	2,583,615	504,651	41.3	19.5	33.8	3,713,735	59.4
Illinois	96,205	6,072,587	1,218,062	63.1	20.1	35.2	5,071,997	52.7
Michigan	13,786	282,470	52,202	20.5	18.5	32.4	473,333	34.3
Wisconsin	35,215	844,974	134,761	24.0	15.9	34.8	1,377,630	39.1
East North Central	252,939	11,330,546	2,213,184	44.8	19.5	34.9	13,136,688	51.9
Minnesota	70,048	3,324,179	712,088	47.5	21.4	31.3	3,149,665	45.0
Iowa	147,267	9,336,228	1,910,180	63.4	20.5	37.3	10,275,619	69.8
Missouri	93,577	4,113,215	1,051,476	44.0	25.6	26.1	3,934,599	42.0
North Dakota	19,030	827,429	190,448	43.5	23.0	19.2	542,310	28.5
South Dakota	57,270	4,075,188	1,048,551	71.2	25.7	16.9	2,161,022	37.7
Nebraska	84,053	7,644,780	1,831,245	91.0	24.0	23.4	3,995,869	47.5
Kansas	62,053	3,830,528	1,031,246	61.7	26.9	19.1	2,264,635	36.5
West North Central	533,298	33,151,547	7,775,234	62.1	23.5	26.4	26,323,719	49.4
Delaware	753	23,852	6,750	31.7	28.3	30.9	6,062	8.1
Maryland	3,109	93,270	21,673	30.0	23.2	33.2	70,590	22.7
Virginia	7,489	196,836	42,667	26.3	21.7	25.6	221,411	29.6
West Virginia	1,425	32,403	7,605	22.7	23.5	30.9	44,259	31.1
North Carolina	4,109	123,743	27,634	30.1	22.3	21.5	144,664	35.2
South Carolina	1,810	133,590	29,419	73.8	22.0	14.6	87,862	48.5
Georgia	787	66,339	13,607	84.3	20.5	11.7	44,613	56.7
Florida	1,371	75,819	18,429	55.3	24.3	12.6	57,144	41.7
South Atlantic	20,853	745,609	167,784	35.8	22.5	21.9	676,605	32.4
Kentucky	23,347	797,503	192,056	34.2	24.1	23.8	653,567	28.0
Tennessee	18,815	633,547	148,360	33.7	23.4	23.0	484,941	25.8
Alabama	4,489	182,505	44,248	40.7	24.2	12.6	94,371	21.0
Mississippi	344	23,838	6,179	69.3	25.9	16.9	16,282	47.3
Arkansas	12,296	266,964	67,600	21.7	25.3	17.9	225,756	18.4
Louisiana	1,042	49,082	12,995	47.1	26.5	15.3	12,073	11.6
Oklahoma	40,481	1,207,166	333,658	29.8	27.6	17.5	987,067	24.4
Texas	35,807	1,097,338	295,151	30.6	26.9	16.9	894,881	25.0
South Central	136,621	4,257,943	1,100,247	31.2	25.8	19.0	3,368,938	24.7
Montana	3,340	63,487	16,932	19.0	26.7	13.9	122,767	36.8
Idaho	6,244	13,450	1,907	2.2	14.2	32.3	272,738	43.7
Wyoming	2,454	152,041	42,358	62.0	27.9	13.5	61,222	24.9
Colorado	13,700	1,391,159	399,989	101.5	28.8	12.4	348,182	25.4
New Mexico	2,996	171,061	50,482	57.1	29.5	13.3	52,944	17.7
Arizona	102	314	35	3.1	11.1	27.9	11,300	110.8
Utah	2,021	2,766	159	1.4	5.7	28.1	49,559	24.5
Nevada	236	688	195	2.9	28.3	44.4	15,095	64.0
Washington	3,278	4,779	452	1.5	9.5	35.7	165,882	50.6
Oregon	4,015	16,118	1,458	4.0	9.0	36.4	177,852	44.3
California	2,525	7,828	1,569	3.1	20.0	32.0	403,961	160.0
Western	40,911	1,823,691	515,536	44.6	28.3	12.9	1,681,502	41.1
United States	989,477	51,385,085	11,787,124	51.9	22.9	26.7	45,613,270	46.1

[1] Gross benefit payments due on corn may be calculated by multiplying the retired acreage by the indicated average yield and this resulting production by 0.35.

[2] Gross benefit payments due on hogs may be calculated at the rate of $1.50 per head in the adjusted hog base. For the United States, gross payments due on hogs approximate $68,419,905; on corn $111,150,674, from which county-association administrative expenses are deductible.

Agricultural Adjustment Administration.

Table 16.—*Hunters' licenses issued by States, with money returns, for the seasons 1933 and 1934* [1]

State	Licenses issued						Money returns	
	Resident		Nonresident and alien		Total			
	1933	1934	1933	1934	1933	1934	1933	1934
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Dollars*	*Dollars*
Alabama	54,042	66,775	127	305	[2] 54,169	67,080	[2] 68,738.65	89,801.00
Alaska	(3)	(3)	89	100	89	100	5,130.00	5,720.00
Arizona	[4] 20,067	[4] 20,514	[4] 258	[4] 182	[4] 20,325	[4] 20,696	55,612.00	55,075.00
Arkansas	41,512	46,238	725	640	42,237	46,878	53,525.80	54,458.60
California	153,347	173,402	656	500	154,003	173,902	453,159.15	334,429.00
Colorado	[4] 71,208	[4] 70,271	170	326	[4] 71,378	[4] 70,597	173,692.00	164,465.00
Connecticut	[4] 27,769	[4] 26,496	[4] 447	[4] 395	[4] 28,216	[4] 26,891	100,718.00	98,347.00
Delaware	1,128	[4] 1,582	71	64	1,199	[4] 1,646	2,433.00	2,549.00
Florida	38,400	40,896	323	304	38,723	41,200	89,977.50	97,888.50
Georgia	[5] 39,227	43,851	----	216	39,227	44,067	86,000.00	62,338.00
Idaho	63,938	67,575	[4] 387	[4] 3,879	[4] 64,325	[4] 71,454	126,412.70	140,555.35
Illinois	280,525	269,308	708	841	281,233	270,149	221,013.75	145,016.00
Indiana	[4] 340,386	[4] 324,383	[4] 155	[4] 199	[4] 340,541	[4] 324,582	342,788.50	294,985.00
Iowa	225,027	[4] 78,565	69	51	[4] 225,096	[4] 78,616	226,062.00	163,171.50
Kansas	78,089	78,069	131	126	78,220	78,195	90,152.00	78,951.00
Kentucky	71,154	85,321	95	138	71,249	85,459	61,330.90	73,902.85
Louisiana	58,971	57,035	396	472	59,367	57,507	61,861.00	60,310.00
Maine	[4] 99,519	[4] 92,747	3,561	3,628	[4] 103,080	[4] 96,375	102,814.93	99,689.50
Maryland	62,078	82,540	1,077	1,759	62,155	84,299	105,710.30	138,428.20
Massachusetts	73,803	[4, 6] 74,698	424	366	74,227	75,064	159,798.40	155,847.75
Michigan	396,383	430,000	2,707	3,780	399,090	433,780	484,163.76	556,500.00
Minnesota	253,161	259,616	136	204	253,297	259,820	254,710.30	294,003.80
Mississippi	[2] 80,109	81,705	[2] 235	301	80,344	82,006	110,463.00	115,291.00
Missouri	[4] 160,170	[4] 154,061	[4] 459	[4] 590	[4] 160,629	[4] 154,651	196,550.17	230,539.00
Montana	[4] 82,763	[4] 89,481	99	[4] 106	[4] 82,862	[4] 89,587	143,092.00	153,901.00
Nebraska	[4] 138,926	[4] 134,612	[4] 453	460	[4] 139,379	[4] 135,072	143,456.00	139,177.00
Nevada	5,220	5,190	60	89	5,280	5,279	13,665.00	13,895.00
New Hampshire	[4] 48,395	[4] 50,204	[4] 4,737	[4] 1,704	[4] 53,132	[4] 51,908	120,036.08	118,450.00
New Jersey	[4] 107,696	[4] 116,061	[4] 877	[4] 940	[4] 108,573	[4] 117,001	227,815.20	273,489.00
New Mexico	[4] 14,873	[4] 15,998	[4] 824	[4] 1,107	[4] 15,697	[4] 17,105	72,456.91	80,688.25
New York	[4] 520,232	[4] 525,440	[4] 3,170	[4] 3,929	[4] 523,402	[4] 529,369	982,051.08	995,670.94
North Carolina	65,966	[4] 125,622	656	[4] 890	66,622	[4] 126,512	110,281.37	[7] 123,798.50
North Dakota	[4] 37,335	23,606	57	6	[4] 37,392	23,612	64,284.34	35,805.69
Ohio	379,768	422,222	29	72	379,797	422,294	380,203.00	423,302.00
Oklahoma	91,858	80,790	435	406	92,293	81,196	94,219.50	85,324.00
Oregon	[4] 50,563	[4] 55,633	257	376	[4] 50,820	[4] 56,009	173,579.00	202,319.00
Pennsylvania	524,337	568,666	4,966	6,024	529,303	574,690	1,069,236.15	[7] 1,227,692.00
Rhode Island	9,030	8,044	166	141	9,196	8,185	19,661.00	17,438.00
South Carolina	57,765	71,836	1,335	1,571	59,100	73,407	99,730.00	124,453.00
South Dakota	69,224	62,115	714	490	69,938	62,605	93,986.00	86,426.00
Tennessee	[4] 47,935	[4] 55,185	67	146	[4] 48,002	[4] 55,331	82,347.58	95,678.21
Texas	85,000	82,227	272	246	85,272	82,473	163,266.00	157,532.72
Utah	[4] 33,177	[4] 45,227	408	644	[4] 33,585	[4] 45,871	83,123.50	101,568.90
Vermont	[4] 44,463	[4] 45,336	1,102	1,125	[4] 45,565	[4] 41,461	61,816.05	62,625.10
Virginia	[2, 4] 121,156	[4] 125,027	[2] 1,250	1,089	[2] 122,406	[4] 126,116	[2] 180,982.15	203,992.50
Washington	[4] 126,668	[4] 153,273	[4] 928	[4] 61	[4] 127,596	[4] 153,340	302,054.50	355,678.00
West Virginia	[4] 144,757	[4] 158,166	[4] 322	[4] 223	[4] 145,079	[4] 158,389	169,457.00	187,969.00
Wisconsin	184,142	213,269	173	239	184,315	213,508	170,053.00	199,742.10
Wyoming	[4] 16,943	[4] 17,205	[4] 345	[4] 506	[4] 17,288	[4] 17,711	68,265.00	90,103.00
Total	5,698,205	5,876,083	37,108	41,962	5,735,313	5,918,045	8,731,835.22	9,068,880.96

[1] Figures are for licenses sold during the calendar year named, or for the season beginning in that year.
[2] Correction of error 1933.
[3] None required.
[4] Includes combined hunting and fishing or hunting and trapping licenses.
[5] Includes resident and nonresident; no separate record kept.
[6] Includes 5,858 free licenses to residents 70 years of age or over.
[7] Returns incomplete.

Biological Survey.

TABLE 17.—*Temperature: Normal [1] and 1935, by months, at selected points in the United States*

Station	January		February		March		April		May		June		July		August		September		October		November		December		Annual	
	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935
	° F.		° F.		° F.		° F.		° F.		° F.		° F.		° F.		° F.		° F.		° F.		° F.		° F.	
Greenville, Maine	12.2	7.4	13.3	13.3	24.9	24.0	36.5	37.4	49.6	46.8	59.0	59.8	65.0	66.7	62.2	64.6	52.4	52.7	44.9	44.2	31.3	34.8	18.6	15.0	39.2	38.9
Burlington, Vt	18.8	12.1	19.4	16.6	29.1	29.6	43.3	41.4	56.5	50.5	65.7	64.1	70.3	71.2	67.9	67.8	60.3	56.6	49.2	49.0	36.3	38.3	24.4	18.2	45.1	42.9
Boston, Mass	27.9	23.2	28.8	27.8	35.6	38.4	46.4	45.2	57.1	55.5	66.5	65.5	71.7	72.6	69.9	70.7	63.2	61.4	53.6	53.8	42.0	45.4	32.5	27.1	49.6	48.9
Buffalo, N. Y	24.6	23.8	24.3	23.8	31.1	36.2	42.8	41.0	54.6	49.4	64.4	63.6	69.8	73.7	68.6	70.2	62.4	59.6	51.9	51.6	39.4	41.2	29.8	24.3	47.0	46.5
Canton, N. Y	16.3	11.0	18.0	15.2	27.7	30.1	42.5	42.0	56.2	50.3	65.1	63.8	68.9	71.9	66.6	68.3	59.3	56.0	47.2	48.5	33.9	37.0	22.7	15.0	43.7	42.4
Trenton, N. J	30.5	29.0	30.7	30.6	39.1	43.8	49.8	49.6	61.1	59.0	69.5	69.8	74.5	77.0	73.0	73.4	66.9	64.0	55.6	55.5	44.4	48.1	34.4	29.3	52.5	52.4
Pittsburgh, Pa	30.7	32.1	32.3	33.2	39.6	47.6	51.2	50.0	62.4	58.8	70.7	70.1	74.6	76.0	72.9	72.0	66.4	63.4	55.7	53.8	43.2	43.0	34.2	24.8	52.8	52.1
Scranton, Pa	26.6	24.8	27.3	27.7	35.7	39.5	48.1	46.0	59.4	55.0	67.8	67.6	71.7	74.8	69.8	70.8	62.9	60.2	51.9	52.6	40.5	43.7	30.7	25.3	49.4	49.0
Cincinnati, Ohio	30.3	33.4	32.8	35.2	40.9	49.4	52.4	50.5	63.1	59.8	71.2	69.2	75.1	78.8	73.6	75.5	67.1	67.1	55.7	57.2	42.5	44.1	33.4	27.2	53.2	54.0
Cleveland, Ohio	26.5	28.9	27.4	28.6	34.6	43.2	46.2	44.6	57.9	53.4	67.1	66.0	71.4	76.2	70.0	72.0	63.9	63.7	53.6	54.0	40.9	43.6	31.2	26.9	49.2	50.1
Evansville, Ind	33.5	37.0	36.3	39.1	45.9	52.9	56.7	55.1	66.7	63.4	75.1	71.6	78.9	81.8	77.4	79.1	70.7	70.8	59.4	61.2	46.6	45.8	37.1	29.8	57.0	57.3
Indianapolis, Ind	28.4	32.0	31.1	33.0	40.0	47.4	52.1	49.0	62.9	58.0	71.6	68.6	75.7	78.6	73.7	75.6	66.9	67.6	55.7	56.2	42.3	41.6	32.2	25.9	52.7	52.8
Fort Wayne, Ind	26.4	27.6	28.0	28.8	36.4	42.7	48.7	46.2	59.6	55.2	69.4	67.0	74.2	77.2	71.4	73.8	65.3	64.3	53.6	52.8	40.9	40.0	29.8	23.9	50.3	50.0
Chicago, Ill	23.7	25.6	26.3	29.6	35.3	41.3	46.9	44.0	57.5	52.0	67.3	65.1	72.5	76.8	71.6	73.4	65.2	65.8	54.0	54.2	40.1	39.6	28.8	25.2	49.1	49.4
Peoria, Ill	23.1	26.2	25.9	31.4	37.0	44.3	50.9	48.4	61.7	55.8	70.9	67.4	75.4	79.2	72.5	74.8	64.3	65.8	52.0	54.4	37.5	38.6	28.1	23.2	49.9	51.8
Cairo, Ill	34.9	38.6	38.5	41.8	47.2	55.2	58.1	56.4	68.4	65.2	76.3	72.6	79.6	81.2	77.8	79.6	71.5	71.4	60.4	61.6	47.3	47.1	37.8	33.0	58.2	58.6
Grand Rapids, Mich	24.5	24.8	23.7	25.6	33.4	38.2	47.0	44.9	58.0	53.3	67.8	64.8	72.3	76.5	69.7	72.2	62.7	62.0	51.2	51.9	38.4	39.2	28.5	26.1	48.1	48.3
Alpena, Mich	19.1	19.1	18.0	19.6	25.5	30.5	38.6	40.2	50.5	48.4	60.4	60.0	65.9	71.7	64.1	66.4	57.6	56.2	47.1	47.4	34.4	35.8	24.8	21.8	42.2	43.1
Marquette, Mich	16.3	16.4	16.3	21.6	24.8	29.2	37.8	36.5	49.0	47.0	58.9	56.2	64.9	69.8	63.8	66.0	57.5	55.6	46.7	46.4	33.3	30.8	22.6	23.2	41.0	41.6
Madison, Wis	16.7	16.8	19.1	24.1	30.6	36.0	45.4	43.4	57.6	52.5	67.2	63.4	72.1	76.3	69.8	71.2	62.4	62.4	50.3	50.5	35.2	34.0	22.8	20.7	45.8	45.9
Green Bay, Wis	15.7	14.7	17.4	21.2	28.6	33.1	43.2	41.4	54.9	52.0	64.9	62.0	70.0	75.4	67.7	69.4	60.4	59.4	48.5	48.1	34.0	33.6	22.3	21.9	44.0	44.4
Duluth, Minn	7.9	5.2	11.4	19.8	23.7	25.4	37.0	35.7	47.3	47.9	57.2	56.2	63.9	68.1	62.6	63.9	55.1	53.0	44.1	43.4	30.0	23.2	15.9	15.4	38.0	38.1
Minneapolis, Minn	12.7	11.0	15.9	25.5	29.6	34.0	46.4	44.0	57.7	54.9	67.5	64.3	72.3	79.8	69.9	72.6	61.4	62.2	48.9	48.6	32.4	28.6	19.6	17.6	44.5	45.3
Des Moines, Iowa	20.1	23.0	23.7	30.6	35.9	41.7	50.1	48.3	61.3	56.0	70.6	67.2	75.4	80.9	73.1	75.0	65.6	66.2	53.4	52.2	38.4	35.7	26.0	24.1	49.5	50.1
Dubuque, Iowa	19.1	19.4	22.2	27.2	34.0	39.4	48.6	47.0	60.3	55.4	69.4	65.6	74.1	79.2	71.7	73.1	64.0	65.2	51.9	52.0	37.0	34.7	24.7	21.8	48.1	48.3
St. Louis, Mo	31.1	34.1	34.8	38.5	44.1	51.2	56.1	52.4	67.0	61.4	75.0	71.5	78.8	82.2	77.5	78.6	70.5	71.4	58.8	58.6	45.4	43.4	34.9	30.3	56.2	56.1
St. Joseph, Mo	27.8	30.2	32.3	35.2	42.1	49.0	54.4	51.0	64.2	58.2	74.4	69.5	79.2	85.1	76.8	78.4	68.9	68.6	56.9	55.0	43.6	39.4	30.8	30.6	54.3	54.2
Springfield, Mo	33.5	35.4	35.2	39.2	45.2	32.8	56.0	53.3	64.5	60.7	72.5	64.0	76.8	80.6	75.7	78.6	68.9	69.0	58.2	58.1	45.7	42.6	36.2	33.0	55.7	54.4
Bismarck, N. Dak	7.8	8.6	10.3	27.6	24.2	27.6	42.1	40.2	54.5	50.1	63.7	62.2	69.8	75.8	67.3	68.0	58.1	60.2	44.9	44.4	28.5	21.1	14.7	15.3	40.5	41.8
Devils Lake, N. Dak	1.8	−2.3	5.1	21.3	19.8	22.7	38.8	37.6	52.6	49.5	61.9	59.7	67.4	73.4	64.8	64.0	55.9	55.4	42.4	41.8	24.5	14.3	9.5	8.3	37.0	37.1
Pierre, S. Dak	16.0	19.0	18.6	34.5	31.5	39.0	46.8	43.0	58.0	53.6	68.5	67.6	75.3	84.4	72.8	77.0	63.8	66.8	49.8	50.4	33.6	31.0	21.8	25.0	46.4	49.3
North Platte, Nebr	22.9	29.2	26.6	35.4	36.6	42.8	48.6	45.9	58.7	52.2	67.5	67.0	72.9	80.9	70.8	75.0	62.1	64.2	49.7	49.9	36.6	35.2	26.7	30.5	48.3	50.7
Omaha, Nebr	21.9	25.2	25.5	33.8	37.0	44.4	51.2	49.4	62.4	56.4	71.6	68.2	76.7	83.7	74.4	76.7	66.8	66.8	54.3	50.6	38.5	35.6	26.4	27.2	50.6	51.5
Concordia, Kans	26.4	30.6	29.8	37.3	41.0	48.4	53.5	51.2	63.2	57.6	73.0	69.6	78.0	84.8	76.5	79.5	68.3	69.0	55.9	53.4	41.4	38.8	30.7	32.0	53.1	54.4
Dodge City, Kans	29.0	36.0	33.2	39.8	42.8	50.4	53.6	51.8	63.5	57.4	72.5	71.4	78.4	83.6	77.7	80.2	69.4	68.7	56.1	56.8	42.6	40.4	32.6	35.4	54.3	56.0
Iola, Kans	29.8	35.6	33.2	40.2	44.5	53.7	56.2	54.3	65.2	61.9	74.1	71.6	78.2	83.9	77.1	80.4	69.8	69.8	57.8	58.5	44.1	43.5	33.9	34.3	55.3	57.3
Washington, D. C	33.4	33.3	35.3	35.4	42.6	50.2	53.3	51.9	63.7	61.8	72.2	73.4	76.8	79.4	75.0	76.8	68.1	67.0	57.4	58.2	45.2	50.2	36.6	32.1	55.0	55.8
Lynchburg, Va	37.5	36.2	40.3	40.2	47.3	52.2	57.3	54.3	67.3	64.2	74.6	73.5	77.5	78.3	75.6	76.8	69.0	68.5	58.5	59.0	47.2	51.6	39.5	32.4	57.6	57.3
Norfolk, Va	40.6	39.9	42.7	42.8	48.2	54.3	56.8	54.7	66.2	65.0	74.4	75.9	78.7	78.2	77.4	77.4	71.6	71.4	62.5	62.0	51.4	55.6	43.1	37.2	59.5	59.5
Parkersburg, W. Va	32.5	33.4	34.2	35.2	42.8	50.4	53.4	51.4	63.8	59.7	71.4	69.8	75.4	77.6	73.9	74.2	67.3	65.8	56.1	55.7	43.8	45.7	35.2	28.2	54.2	53.9

Lexington, Ky	32.9	34.8	35.4	37.8	43.7	52.0	54.3	55.4	64.3	66.5	72.2	70.1	75.9	79.1	74.5	76.4	68.5	68.3	57.4	58.1	44.8	45.3	35.8	28.7	55.0	56.0
Charlotte, N. C	41.2	41.9	43.9	44.0	50.4	57.0	59.8	59.2	68.9	68.0	75.5	77.6	78.4	79.4	77.1	78.8	71.5	71.9	61.7	62.5	50.6	54.2	43.0	35.9	60.2	60.9
Wilmington, N. C	46.5	47.6	47.9	48.6	53.3	60.6	62.0	61.6	70.8	69.1	76.8	77.6	79.1	77.8	77.6	78.8	73.1	74.0	65.3	65.2	56.0	57.6	49.1	40.9	63.1	63.3
Charleston, S. C	49.9	51.4	52.4	51.2	57.4	63.4	64.5	66.4	72.7	73.6	78.9	80.2	81.4	79.3	81.0	81.2	76.6	76.0	67.8	68.4	58.1	60.4	51.7	44.6	66.0	66.3
Greenville, S. C	40.3	43.0	43.3	43.9	49.9	55.4	58.6	60.0	67.2	68.4	74.1	76.0	76.9	78.4	75.8	77.7	70.6	72.4	60.2	63.2	49.6	54.6	42.2	36.8	59.1	60.8
Atlanta, Ga	42.6	44.0	45.3	45.0	52.0	57.6	61.0	61.2	69.9	70.4	76.0	76.3	78.1	79.7	77.0	79.8	72.4	73.4	63.0	63.8	52.1	53.8	44.7	36.2	61.2	61.8
Thomasville, Ga	51.0	53.4	55.0	54.0	60.2	64.6	66.7	67.3	74.0	74.1	79.5	79.6	81.8	79.8	81.0	80.8	76.8	76.1	68.2	70.4	58.5	60.2	52.5	46.4	67.1	67.2
Jacksonville, Fla	55.4	54.2	58.0	56.8	62.6	68.8	68.7	70.4	75.0	77.0	79.9	81.4	82.1	80.8	81.7	82.6	78.3	78.0	71.1	72.4	62.2	64.0	56.3	49.5	69.3	69.9
Miami, Fla	66.5	66.8	67.1	66.6	70.2	72.8	72.8	75.2	76.4	80.2	80.0	80.4	81.0	81.6	81.4	83.0	80.1	80.7	77.0	78.0	71.8	72.0	68.0	62.0	74.4	74.9
Memphis, Tenn	40.9	43.2	44.3	45.2	52.3	59.0	61.8	59.8	70.6	68.2	77.6	75.2	80.7	82.6	79.4	81.8	73.6	74.1	63.3	65.1	51.7	50.4	43.6	37.2	61.6	61.8
Nashville, Tenn	38.6	40.6	41.6	42.6	49.2	57.2	59.0	58.0	68.2	67.2	75.6	72.9	79.1	80.1	77.8	80.0	71.8	71.2	61.0	62.2	49.0	49.2	41.0	34.0	59.3	59.6
Birmingham, Ala	45.1	46.4	48.0	48.0	55.4	61.2	63.3	63.2	71.1	72.0	77.9	75.9	80.2	82.0	79.2	82.2	74.8	76.4	64.8	68.0	53.9	54.6	46.4	38.8	63.3	64.1
Mobile, Ala	51.5	52.7	54.7	54.7	59.7	63.8	66.3	67.6	74.4	75.4	80.3	79.4	81.4	82.0	81.0	82.0	78.1	77.2	69.3	71.2	58.6	59.6	52.2	46.9	67.3	67.7
Meridian, Miss	47.0	48.8	49.6	50.6	57.1	63.3	64.0	64.9	71.3	73.4	78.1	77.8	80.4	82.0	79.5	82.8	74.5	75.3	64.3	68.2	54.2	55.2	47.7	41.9	64.0	65.4
Vicksburg, Miss	48.2	50.7	51.8	52.0	58.5	64.0	65.6	64.9	72.9	73.2	79.0	78.0	81.3	83.0	80.8	82.6	76.3	75.6	66.7	69.4	56.6	55.8	50.0	44.2	65.6	66.1
New Orleans, La	54.2	56.9	57.3	58.2	62.8	68.1	68.8	70.3	75.4	77.8	80.6	81.9	82.4	83.6	82.2	84.2	79.2	79.4	71.0	74.0	61.6	62.3	55.6	51.0	69.3	70.6
Shreveport, La	47.0	50.8	50.9	52.2	58.3	64.4	65.8	65.9	73.6	71.6	80.7	80.0	83.2	84.8	82.0	84.8	76.9	75.8	66.6	70.4	56.0	56.0	49.1	45.4	65.8	66.8
Amarillo, Tex	35.3	44.2	38.1	43.3	46.9	53.1	55.8	56.8	64.1	60.9	72.8	74.4	76.8	80.1	75.7	79.2	69.3	67.6	57.7	61.8	45.5	46.2	37.0	39.5	56.3	58.9
Brownsville, Tex	59.8	65.7	62.6	61.6	68.2	71.4	73.7	75.5	78.6	79.2	82.4	82.1	83.6	83.8	83.9	84.2	80.6	79.6	74.9	76.7	67.2	69.2	61.2	60.8	73.1	74.2
El Paso, Tex	45.0	48.8	49.0	48.6	55.8	58.6	63.4	65.3	71.5	68.4	79.6	81.2	81.1	84.0	79.2	81.6	73.9	73.4	63.5	67.1	52.7	53.4	44.9	46.5	63.3	64.7
Fort Worth, Tex	45.4	49.7	48.3	49.6	57.7	63.4	65.0	64.6	72.3	69.5	79.9	78.6	83.6	85.1	83.0	85.7	76.9	73.4	66.7	69.0	55.5	51.8	47.5	45.5	65.2	65.5
Galveston, Tex	53.8	57.6	56.3	56.8	62.4	66.0	68.7	70.2	74.8	75.8	80.7	81.9	83.4	83.2	83.0	84.8	80.1	78.8	72.7	75.0	63.3	62.8	56.4	54.6	69.6	70.6
San Antonio, Tex	52.3	57.0	55.4	56.2	62.8	67.3	69.1	70.4	75.1	72.6	81.0	79.5	83.8	83.7	83.5	84.9	79.0	77.0	70.5	74.0	60.3	60.3	53.7	52.0	68.9	69.6
Oklahoma City, Okla	36.4	42.4	39.6	43.9	50.0	57.2	59.8	57.8	67.7	64.2	76.0	74.4	80.6	84.6	79.7	84.2	72.8	70.6	61.5	62.6	48.8	45.2	39.3	39.1	59.4	60.5
Little Rock, Ark	41.4	43.4	44.9	46.4	53.0	59.6	62.1	60.2	70.3	67.0	77.4	75.5	80.9	82.3	79.8	82.2	74.1	73.8	63.6	64.3	52.1	49.8	44.2	38.4	62.0	61.9
Havre, Mont	12.9	8.3	13.6	28.2	27.1	26.2	43.7	38.2	53.4	51.6	62.0	61.8	68.3	73.2	65.4	65.8	56.4	57.6	44.5	45.6	31.2	25.2	20.4	25.0	41.6	42.2
Miles City, Mont	14.5	13.4	16.8	33.2	28.6	30.9	44.7	42.2	56.7	52.9	66.0	64.6	72.9	78.5	71.5	71.0	61.2	61.1	46.5	46.7	30.9	30.2	21.0	26.2	44.3	45.9
Kalispell, Mont	20.4	21.6	23.3	27.8	32.9	31.9	43.6	38.2	51.4	50.9	57.7	57.5	64.1	65.2	62.8	62.2	53.5	57.5	43.5	43.0	32.4	28.0	24.9	28.8	42.5	42.7
Cheyenne, Wyo	25.5	33.3	27.3	32.8	33.1	35.1	40.9	38.0	50.3	44.6	60.4	59.8	66.7	69.8	65.6	67.8	57.0	57.8	44.8	44.7	34.8	33.0	28.5	29.4	44.6	45.5
Sheridan, Wyo	18.8	22.4	22.0	32.0	31.3	32.0	43.4	39.0	52.0	48.2	61.0	60.6	67.8	73.8	66.2	67.4	56.2	58.8	44.4	44.5	32.4	28.2	22.5	28.7	43.2	44.6
Pueblo, Colo	29.9	38.4	32.9	38.8	41.6	45.6	50.1	50.8	59.2	55.4	69.0	70.0	74.2	78.2	72.7	75.8	64.6	65.2	52.0	54.0	39.4	39.6	31.5	33.2	51.4	53.8
Grand Junction, Colo	24.0	34.0	32.9	37.8	43.6	42.2	52.4	51.9	61.1	59.2	71.4	74.2	77.7	80.1	75.4	76.6	66.2	68.6	52.8	54.8	39.3	38.8	27.5	30.6	52.0	54.1
Sante Fe, N. Mex	28.8	34.7	33.1	34.5	39.7	40.8	46.7	46.8	55.7	50.9	64.8	66.2	69.0	70.6	67.4	67.6	60.9	61.4	50.4	51.5	38.9	38.7	30.7	31.2	48.8	49.6
Roswell, N. Mex	39.2	45.0	42.5	44.4	51.3	55.2	60.6	61.2	69.4	63.8	76.3	75.9	78.9	78.2	76.6	78.8	70.3	66.7	59.5	62.1	48.1	48.5	41.2	40.7	59.5	60.0
Phoenix, Ariz	51.2	53.8	55.1	57.9	60.7	57.6	67.0	69.4	75.0	74.1	84.5	89.2	89.8	92.0	88.5	88.4	82.7	84.6	70.6	72.6	59.7	57.2	52.0	54.3	69.7	70.9
Modena, Utah	26.7	30.8	31.0	35.8	38.2	36.3	46.0	46.8	53.5	52.6	63.3	67.0	70.6	69.8	69.2	71.0	60.0	63.3	48.0	48.2	36.4	34.8	28.1	28.8	47.6	48.8
Salt Lake City, Utah	29.2	33.8	33.8	37.4	41.7	41.0	49.6	49.8	57.4	55.4	67.4	69.9	75.7	78.4	74.5	75.6	64.4	67.8	52.5	51.4	41.1	36.3	31.9	32.2	51.6	52.4
Winnemucca, Nev	28.6	30.8	33.5	36.2	40.0	36.0	46.7	46.0	53.9	53.8	62.8	65.7	70.6	72.0	69.3	71.6	59.2	64.6	48.3	47.2	38.4	32.8	30.0	31.6	48.4	49.0
Boise, Idaho	29.8	31.0	34.8	33.2	42.7	39.8	50.4	48.8	57.1	56.6	65.3	66.1	72.9	74.2	71.8	72.2	61.9	67.0	51.1	51.9	41.0	34.4	32.1	29.0	50.9	50.4
Seattle, Wash	39.5	41.6	41.1	45.0	44.9	43.6	49.4	50.7	54.5	56.6	59.0	61.6	63.1	64.9	63.1	64.7	58.1	62.7	51.4	51.4	45.6	43.5	41.7	45.0	51.0	52.6
Walla Walla, Wash	32.7	36.4	37.1	39.8	46.1	44.0	53.1	49.5	59.6	60.2	66.5	67.6	74.0	75.0	72.7	72.7	63.8	69.4	53.5	53.2	42.8	37.1	35.5	33.6	53.1	53.2
Portland, Oreg	39.4	40.4	42.1	46.2	46.9	44.0	51.8	51.7	56.9	57.8	62.4	64.4	66.7	67.8	66.7	68.4	61.7	67.2	54.2	53.3	46.8	42.4	41.2	42.2	53.1	53.8
Roseburg, Oreg	41.2	41.5	43.4	46.8	47.1	44.2	51.0	52.4	56.0	57.1	62.5	64.6	67.4	68.3	68.0	69.6	62.9	67.8	53.9	54.0	45.9	43.7	41.8	40.6	53.4	54.2
Eureka, Calif	46.9	47.7	47.2	50.4	48.3	45.3	49.9	51.2	52.0	51.4	54.3	55.7	55.5	55.3	56.0	55.4	55.9	54.8	53.6	52.6	51.1	48.4	48.2	49.8	51.6	51.5
Fresno, Calif	46.2	46.8	51.1	50.8	55.0	51.2	60.2	60.6	67.1	67.5	75.8	78.2	82.1	80.2	80.7	82.2	73.4	76.4	64.0	63.2	54.2	51.8	46.2	49.6	63.0	63.2
Los Angeles, Calif	54.6	57.0	55.5	60.0	57.5	55.3	59.4	60.7	62.2	62.0	66.4	66.4	70.2	70.8	71.1	74.0	69.0	69.8	65.3	67.0	60.9	60.8	56.6	59.4	62.4	63.6
Sacramento, Calif	45.8	46.4	50.1	50.0	54.3	50.4	58.1	58.6	63.3	63.9	69.4	74.2	73.2	74.4	72.9	76.4	69.3	71.0	62.9	62.4	53.6	50.8	46.2	47.7	59.9	60.5
San Diego, Calif	54.3	56.0	55.1	57.4	56.7	54.6	58.5	60.0	60.8	61.6	63.9	63.4	67.2	67.8	68.7	70.4	67.1	67.3	63.7	64.1	59.7	58.0	56.0	57.4	61.0	61.5
San Francisco, Calif	49.9	50.8	52.2	54.1	54.2	52.6	55.0	58.7	56.8	58.7	58.5	61.3	58.5	60.2	59.1	60.0	60.9	60.6	60.5	61.0	56.3	54.8	51.3	52.8	56.1	57.1

[1] Normals are based on records of 30 or more years of observations.

Weather Bureau.

TABLE 18.—*Precipitation: Normal*[1] *and 1935, by months, at selected points in the United States*

Station	January		February		March		April		May		June		July		August		September		October		November		December		Annual	
	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935	Normal	1935
	In.		*In.*		*In.*		*In.*		*In.*		*In.*		*In.*		*In.*		*In.*		*In.*		*In.*		*In.*		*In.*	
Greenville, Maine	2.86	6.86	2.75	2.22	3.06	1.79	3.05	5.37	3.45	2.55	3.85	6.87	4.62	2.87	3.56	2.01	3.85	3.14	3.60	1.02	3.38	4.30	3.14	1.75	41.17	40.75
Burlington, Vt	1.76	2.80	1.57	1.13	2.04	.88	2.15	3.31	2.85	2.31	3.38	6.58	3.50	4.01	3.37	3.26	3.48	4.23	2.97	1.64	2.66	2.45	1.88	1.20	31.61	31.72
Boston, Mass	3.61	6.13	3.37	3.26	3.57	1.52	3.34	4.77	3.18	1.35	2.89	5.07	3.49	1.10	3.62	2.14	3.14	2.69	3.15	.34	3.33	3.91	3.45	.66	40.14	32.94
Buffalo, N. Y	3.30	2.81	2.95	3.00	2.57	1.85	2.56	.88	3.10	2.08	2.82	3.06	3.03	1.34	3.08	.76	2.92	2.58	3.29	1.58	3.02	1.58	3.36	3.21	36.00	24.73
Canton, N. Y	2.50	3.24	2.27	2.08	2.50	1.25	2.18	4.04	3.00	2.27	3.29	4.40	3.50	5.20	3.65	2.87	3.35	3.56	3.03	2.13	3.16	1.68	2.69	1.45	35.12	34.17
Trenton, N. J	3.31	3.27	3.27	2.81	3.40	2.17	2.94	1.46	3.08	1.47	3.09	4.09	3.94	4.07	4.75	3.09	3.40	5.42	2.78	4.73	2.73	4.27	3.35	1.40	40.04	38.25
Pittsburgh, Pa	3.05	2.41	2.62	3.00	3.03	3.04	2.92	1.91	3.21	4.07	3.81	3.35	4.05	2.38	3.23	4.92	2.58	1.96	2.52	2.03	2.29	2.10	2.86	3.27	36.17	34.45
Scranton, Pa	3.03	2.03	3.04	1.87	3.20	2.02	2.77	3.50	3.27	2.84	3.67	4.33	4.03	7.91	3.69	4.95	3.17	3.52	3.03	3.43	2.77	6.16	3.02	1.65	38.69	44.21
Cincinnati, Ohio	3.48	2.86	2.99	1.08	3.89	6.03	3.12	2.26	3.70	4.87	3.66	3.98	3.31	1.48	3.41	4.56	2.65	2.12	2.51	1.95	2.85	2.49	2.98	1.92	38.55	35.60
Cleveland, Ohio	2.51	2.15	2.51	3.26	2.71	2.06	2.44	1.34	3.12	1.87	3.12	1.45	3.45	2.61	2.77	5.70	3.33	2.78	2.78	1.69	2.64	1.71	2.44	2.83	33.82	29.45
Evansville, Ind	3.74	3.35	3.24	1.62	4.19	9.24	3.90	2.90	3.86	9.96	4.04	4.96	3.42	2.53	3.36	2.26	3.31	1.40	2.82	2.92	3.74	2.54	3.54	1.55	43.16	45.23
Indianapolis, Ind	2.95	2.33	2.73	.20	3.93	3.49	3.62	1.54	3.89	6.97	3.62	4.66	3.34	3.16	3.31	4.99	3.40	3.98	2.78	1.01	3.35	3.56	2.98	1.84	39.90	37.73
Fort Wayne, Ind	2.33	2.58	2.35	1.20	3.22	3.34	3.07	2.15	3.85	4.50	3.57	3.00	3.60	2.52	3.11	2.39	3.06	2.39	2.60	1.63	2.88	3.23	2.58	1.53	36.22	30.46
Chicago, Ill	1.90	2.34	2.14	1.59	2.58	3.48	2.78	1.77	3.54	7.09	3.30	5.03	3.33	3.05	3.21	3.56	3.14	3.28	2.53	1.68	2.37	3.62	2.04	1.24	32.86	37.73
Peoria, Ill	1.78	1.93	2.01	2.83	2.73	3.32	3.38	2.91	4.06	8.58	3.77	6.62	3.58	2.64	3.12	.98	4.03	3.33	2.29	1.59	2.37	4.03	1.77	1.39	34.89	40.15
Cairo, Ill	3.76	4.74	3.13	1.34	3.75	12.00	3.72	3.69	3.71	4.83	3.83	7.51	3.07	1.86	3.02	5.99	2.89	1.23	2.76	5.00	3.68	1.70	3.40	1.99	40.72	51.88
Grand Rapids, Mich	2.35	2.04	2.24	1.91	2.48	2.62	2.77	1.35	3.44	4.33	3.48	4.95	2.92	5.17	2.61	2.22	3.53	2.56	2.81	1.08	2.77	5.11	2.57	1.65	33.97	34.99
Alpena, Mich	1.89	2.05	1.71	1.02	1.99	2.51	2.24	.63	3.05	.81	3.30	4.66	2.76	1.54	2.86	2.07	2.98	2.43	2.71	1.30	2.60	1.77	2.08	1.19	30.17	21.98
Marquette, Mich	2.33	2.52	1.90	.72	2.26	1.67	2.43	1.87	2.96	1.44	3.22	3.29	3.12	3.47	2.67	2.35	3.25	1.98	2.76	1.97	2.91	4.08	2.60	2.91	32.47	28.27
Madison, Wis	1.38	1.26	1.50	1.52	2.07	1.58	2.77	1.82	3.85	3.09	3.76	4.94	3.88	2.49	3.21	4.22	3.72	1.28	2.43	1.60	1.78	2.83	1.63	.82	31.98	27.45
Green Bay, Wis	1.54	1.44	1.56	1.28	2.04	.70	2.65	1.70	3.52	1.46	3.70	4.69	3.46	1.70	3.18	4.31	3.52	3.29	2.54	1.21	2.16	1.53	1.71	.90	31.58	24.21
Duluth, Minn	.97	2.61	1.05	.45	1.54	2.04	2.06	1.45	3.25	1.85	3.91	3.57	3.76	4.96	3.18	5.65	3.31	1.96	2.31	2.65	1.45	1.00	1.15	1.11	27.94	29.30
Minneapolis, Minn	.86	1.44	.95	.21	1.42	1.63	2.23	2.32	3.67	3.81	4.22	4.82	3.73	2.59	3.12	3.02	3.13	1.98	2.08	3.95	1.27	.69	.98	1.04	27.66	27.50
Des Moines, Iowa	1.07	1.57	1.12	1.32	1.78	1.10	2.91	.74	4.56	7.18	4.76	7.75	3.50	3.06	3.52	1.85	3.67	5.99	2.50	3.11	1.43	2.68	1.22	.80	32.04	37.15
Dubuque, Iowa	1.30	1.59	1.38	1.54	2.03	2.32	2.85	1.57	4.22	3.95	4.31	4.75	3.94	3.82	3.24	4.62	4.01	2.30	2.48	1.69	1.70	3.44	1.44	.96	32.90	32.55
St. Louis, Mo	2.34	2.76	2.56	1.27	3.38	6.43	3.81	2.50	4.34	7.35	3.82	4.37	2.98	3.13	2.99	1.82	3.46	3.36	2.72	2.56	2.83	2.71	2.21	1.11	37.44	39.36
St. Joseph, Mo	1.05	.72	1.38	1.10	2.04	1.61	3.02	3.10	4.24	7.92	4.94	8.20	3.68	.11	3.50	1.57	3.87	4.23	2.69	3.09	1.63	2.71	.97	.25	33.01	34.61
Springfield, Mo	2.34	2.43	2.35	.99	3.39	9.09	3.86	1.86	5.19	6.81	4.68	11.31	4.21	1.62	4.09	3.93	3.52	2.64	3.05	3.88	2.79	2.50	2.31	.62	41.78	47.68
Bismarck, N. Dak	.45	.04	.44	.29	.89	.99	1.52	3.03	2.32	2.25	3.35	2.82	2.24	5.46	1.82	1.14	1.23	.38	.94	T.	.57	.82	.57	.71	16.34	17.93
Devils Lake, N. Dak	.47	.50	.50	.14	.78	.87	1.52	1.67	2.03	2.16	3.56	1.97	2.57	5.23	2.48	4.52	1.63	.80	1.25	.35	.72	.78	.54	.53	18.05	19.52
Pierre, S. Dak	.46	.17	.46	.82	.86	.74	1.81	4.71	2.49	1.80	2.96	1.50	2.68	.34	2.09	.34	1.10	.16	.82	.18	.47	.04	.50	.35	16.70	11.15
North Platte, Nebr	.39	.18	.53	.31	.86	.56	2.06	4.08	2.78	6.24	3.22	3.18	2.74	1.17	2.39	1.89	1.35	.31	1.07	.22	.47	.78	.53	.27	18.39	19.19
Omaha, Nebr	.70	.22	.89	.91	1.37	1.10	2.51	.80	3.77	3.57	4.56	5.25	3.54	1.11	3.05	2.15	3.21	2.21	2.17	3.14	1.07	1.71	.93	.40	27.77	22.57
Concordia, Kans	.61	.07	.88	.67	1.23	.47	2.36	.72	4.18	6.20	4.41	7.58	3.78	1.23	2.91	5.83	2.60	7.14	1.97	2.14	.99	1.29	.63	.18	26.55	33.52
Dodge City, Kans	.41	.65	.77	.55	.89	.84	1.94	.03	2.89	4.40	3.30	1.95	3.14	1.09	2.67	1.62	1.90	1.77	1.30	1.09	.73	.98	.57	.12	20.51	15.09
Iola, Kans	1.32	1.83	1.67	1.58	2.62	1.63	3.49	2.97	4.70	12.10	5.47	7.48	3.75	.63	3.49	5.49	4.93	2.49	2.99	6.17	1.83	6.82	1.39	.32	37.65	49.51
Washington, D. C	3.55	5.27	3.27	2.37	3.75	3.39	3.27	3.95	3.70	3.54	4.13	3.43	4.71	2.25	4.01	2.40	3.24	8.08	2.84	2.76	2.37	4.03	3.32	2.06	42.16	43.53
Lynchburg, Va	3.43	5.27	3.15	3.18	3.54	5.70	2.95	4.78	3.63	3.26	3.79	8.53	4.21	6.76	3.78	3.80	3.31	7.53	3.15	2.18	2.33	5.05	3.26	2.60	40.53	58.64
Norfolk, Va	3.10	3.10	3.22	3.53	3.77	4.17	3.23	5.22	3.81	2.89	4.22	1.81	5.75	7.80	5.22	3.63	3.23	5.29	3.04	.78	2.16	3.64	3.34	2.33	44.09	44.09
Parkersburg, W. Va	3.58	2.71	3.13	1.68	3.49	4.20	3.19	2.17	3.38	6.41	4.00	4.06	4.29	6.44	3.51	10.42	2.76	4.48	2.48	2.75	2.57	1.78	3.03	3.24	39.41	50.34
Lexington, Ky	4.18	5.36	3.62	2.22	4.32	7.44	3.50	2.10	3.81	1.52	4.05	6.55	3.65	9.66	3.45	5.07	3.07	4.46	2.59	2.81	3.34	4.39	3.77	3.12	43.35	54.70
Charlotte, N. C	4.00	1.68	4.18	3.35	4.17	5.01	3.31	4.02	3.63	3.74	4.22	.50	5.10	8.27	5.07	2.70	2.99	5.47	2.95	.89	2.57	3.64	3.86	2.15	46.05	41.42

Wilmington, N. C	3.29	2.89	3.26	1.74	3.17	1.88	2.66	1.89	3.44	.97	5.10	2.33	7.13	15.97	6.36	10.02	4.51	5.44	3.27	.19	1.96	3.74	2.78	5.01	46.93	52.07
Charleston, S. C	3.02	2.27	2.98	1.93	3.02	1.02	2.53	1.12	3.00	7.09	4.59	3.45	6.89	17.78	6.53	9.53	4.53	5.53	3.27	.14	2.14	1.48	2.72	2.72	45.22	54.06
Greenville, S. C	4.87	3.47	5.18	2.50	5.15	2.92	3.72	4.61	4.03	4.21	4.55	3.08	5.36	6.83	5.50	6.29	3.68	2.01	3.12	1.98	3.18	4.16	4.84	1.67	53.18	43.68
Atlanta, Ga	4.95	1.93	4.79	4.37	5.30	5.23	3.61	4.27	3.47	3.30	3.74	2.33	4.65	4.00	4.45	3.37	2.99	2.68	2.59	2.26	3.03	5.61	4.70	3.06	48.27	42.41
Thomasville, Ga	4.10	3.09	4.46	4.88	4.09	3.28	3.34	4.31	3.63	5.21	5.45	1.58	6.70	12.13	5.75	10.34	4.88	8.52	2.96	.01	2.68	1.64	4.31	2.69	52.35	57.68
Jacksonville, Fla	2.80	2.77	2.97	1.69	2.91	1.13	2.38	2.66	4.02	5.28	5.33	3.03	6.71	9.87	5.81	9.07	7.35	9.15	4.46	.40	1.98	.31	3.02	1.34	49.74	46.70
Miami, Fla	2.52	.32	1.83	.31	2.17	.22	3.09	6.23	6.22	1.06	6.86	6.21	5.42	4.05	6.17	6.36	8.34	8.89	8.44	9.45	2.91	4.29	1.69	.52	55.66	47.91
Memphis, Tenn	4.81	8.74	4.36	2.06	5.26	6.30	4.78	2.82	4.19	8.09	3.55	6.16	3.18	3.46	3.36	.76	2.80	1.97	2.68	7.30	4.24	2.63	4.51	.91	47.72	51.20
Nashville, Tenn	4.76	6.96	4.13	3.63	5.11	6.96	4.13	4.51	3.87	3.51	4.00	2.81	3.88	4.50	3.71	2.29	3.42	2.33	2.49	1.51	3.50	2.77	4.20	.91	47.20	42.69
Birmingham, Ala	5.52	1.98	5.06	5.28	5.70	11.22	4.81	4.78	3.95	4.66	4.46	6.74	5.17	1.77	4.26	3.41	3.38	2.28	2.42	2.59	3.31	5.87	5.14	4.10	53.18	54.68
Mobile, Ala	4.85	2.01	5.33	3.56	5.98	11.23	4.63	5.59	4.32	7.50	5.43	2.99	6.89	6.16	6.92	3.24	5.00	2.97	3.60	1.07	2.64	2.10	5.02	4.98	61.61	53.40
Meridian, Miss	5.32	3.14	5.45	3.72	5.23	9.84	4.78	5.86	4.32	5.75	4.55	1.60	4.89	3.06	4.54	3.32	2.96	3.65	2.39	1.21	3.32	2.35	5.23	4.23	52.98	47.73
Vicksburg, Miss	5.37	2.38	4.82	2.88	5.57	8.18	5.19	2.97	4.32	9.85	3.99	5.26	4.53	1.90	3.46	1.76	2.87	2.08	2.77	1.09	3.71	6.05	5.33	3.42	51.93	47.82
New Orleans, La	4.34	2.93	4.25	3.64	4.72	9.62	5.24	8.35	4.60	4.57	5.88	3.46	6.37	8.43	5.80	4.80	5.03	2.43	3.30	.48	3.14	2.15	4.79	7.06	57.46	57.91
Shreveport, La	3.93	5.50	3.29	3.33	4.11	2.99	4.63	5.16	4.22	10.47	2.50	2.95	3.56	1.02	2.70	2.70	2.80	1.88	2.69	3.88	3.65	6.07	4.29	3.39	43.37	49.34
Amarillo, Tex	.51	.75	.71	.22	.71	1.14	1.83	.05	2.79	2.57	2.84	.28	2.84	.81	3.08	5.32	2.30	2.03	1.66	.87	.92	1.27	.80	.18	20.99	15.49
Brownsville, Tex	1.50	.90	1.21	.27	1.26	.88	1.43	2.04	2.27	1.64	2.87	4.97	1.96	.85	2.55	1.14	5.52	5.20	3.29	2.28	1.98	.95	1.56	3.93	27.40	25.05
El Paso, Tex	.46	.24	.41	.47	.36	.14	.26	.02	.33	.17	.58	.09	1.99	.16	1.70	1.72	1.25	1.24	.80	.14	.50	.92	.52	.34	9.16	5.65
Fort Worth, Tex	2.05	3.70	1.76	3.29	2.32	1.40	4.02	3.06	4.65	9.15	3.35	7.22	2.61	.89	2.62	.70	2.49	3.61	2.81	4.01	2.58	1.65	1.87	2.26	33.13	40.94
Galveston, Tex	3.41	2.83	2.83	5.00	2.68	1.00	3.06	4.17	3.42	.71	4.37	3.89	3.71	5.36	4.28	3.61	5.57	7.40	4.36	1.86	3.33	1.97	3.75	7.22	44.77	45.02
San Antonio, Tex	1.46	.31	1.65	1.87	1.84	2.31	3.19	3.52	3.20	14.07	2.46	8.41	2.17	1.61	2.42	.98	3.05	5.61	2.23	1.94	1.90	.44	1.61	1.86	27.18	42.93
Oklahoma City, Okla	1.19	.60	1.11	.86	1.98	3.77	3.29	1.81	4.88	5.29	3.67	4.11	2.86	1.11	2.89	2.82	3.05	1.91	2.86	2.84	1.87	2.00	1.50	1.81	31.15	28.93
Little Rock, Ark	4.73	6.35	3.84	2.40	4.62	6.09	5.19	3.47	4.78	10.34	3.76	5.51	3.50	2.34	3.75	2.07	3.17	3.40	2.71	3.50	4.19	2.40	4.14	1.87	48.38	49.74
Havre, Mont	.73	.81	.50	.30	.51	.92	.99	1.15	2.04	1.46	2.86	.67	1.87	1.64	1.22	.33	1.29	.17	.67	.56	.61	.33	.61	.19	13.90	8.53
Miles City, Mont	.66	.41	.49	.05	.86	1.65	1.12	.90	2.24	.96	2.66	1.84	1.54	1.83	1.08	1.87	1.04	.14	.90	.64	.57	.48	.63	.77	13.79	11.54
Kalispell, Mont	1.57	1.97	1.11	.25	.95	1.18	.80	1.81	1.46	1.04	2.06	1.03	1.10	1.11	.87	.37	1.24	.14	1.06	.53	1.35	1.02	1.45	1.02	15.02	11.47
Cheyenne, Wyo	.42	.18	.64	.69	1.02	.32	1.99	2.95	2.43	5.89	1.61	2.75	2.10	1.94	1.55	.60	1.20	1.72	.96	.26	.52	.32	.55	.07	14.99	17.69
Sheridan, Wyo	.85	.10	.70	.35	1.16	1.40	1.92	1.34	2.65	3.12	2.04	1.72	1.22	.09	.91	1.90	1.27	.64	1.07	.58	.63	.44	.64	.41	15.06	12.09
Pueblo, Colo	.31	.08	.47	.43	.59	.14	1.31	.42	1.60	1.60	1.36	1.03	1.94	.30	1.82	1.08	.75	2.01	.66	.76	.36	.10	.50	.11	11.67	8.06
Grand Junction, Colo	.60	.77	.58	.46	.76	.60	.83	1.25	.81	.77	.40	.09	.61	.10	1.17	1.15	.92	.82	.95	.13	.57	.44	.63	.82	8.83	7.40
Santa Fe, N. Mex	.67	1.11	.75	.56	.80	.06	1.00	1.02	1.26	2.72	1.08	.07	2.38	1.89	2.28	2.03	1.45	.99	1.18	.58	.68	1.50	.74	.36	14.27	12.89
Roswell, N. Mex	.53	.06	.57	.53	.74	.57	.89	.39	1.09	2.38	1.67	.95	2.26	.41	2.15	1.33	2.11	2.99	1.42	.05	.85	.75	.66	.13	14.94	10.54
Phoenix, Ariz	.80	.95	.77	3.18	.68	1.39	.40	.09	.12	.14	.07	.00	1.07	.93	.95	1.27	.75	1.30	.47	.13	.70	.56	1.00	.39	7.78	10.33
Modena, Utah	.85	.94	.95	.70	1.03	1.21	.89	.47	.79	2.02	.32	T.	1.08	1.51	1.29	1.06	.78	.63	.74	.03	.59	.47	.83	.47	10.14	9.51
Salt Lake City, Utah	1.31	.30	1.51	.72	1.98	1.35	2.05	2.89	1.92	3.68	.80	.13	.51	.04	.85	.80	.98	.54	1.44	.17	1.35	.71	1.43	.88	16.13	12.21
Winnemucca, Nev	1.03	1.30	.91	.96	.96	1.08	.84	3.34	.88	1.49	.72	T.	.21	.01	.20	.01	.41	T.	.62	.43	.68	.51	1.08	1.46	8.54	10.59
Boise, Idaho	1.73	.76	1.44	1.00	1.35	.68	1.18	2.88	1.43	1.04	.92	.06	.24	.03	.19	T.	.53	.10	1.24	.49	1.28	1.05	1.57	1.00	13.10	9.09
Seattle, Wash	4.94	8.90	3.89	2.04	3.05	4.03	2.38	1.55	1.87	.55	1.33	1.81	.63	.79	.70	.50	1.77	1.86	2.84	3.44	5.03	2.07	5.60	4.11	34.03	31.65
Walla Walla, Wash	1.96	1.18	1.76	.83	1.61	1.15	1.51	2.13	1.61	.33	1.12	.86	.39	.20	.49	.19	.95	.10	1.53	1.26	2.02	.50	2.06	1.39	17.01	10.12
Portland, Oreg	6.60	3.45	5.36	3.17	3.91	5.38	2.87	2.48	2.19	.61	1.52	.50	.61	.28	.64	.20	1.98	.86	3.12	3.20	6.10	3.27	6.72	5.89	41.62	29.29
Roseburg, Oreg	5.31	4.36	4.49	2.84	3.28	3.16	2.27	2.85	1.93	.11	1.09	.34	.32	.11	.34	.36	1.27	.40	2.61	4.05	4.66	2.57	5.34	4.70	32.91	25.85
Eureka, Calif	7.11	7.25	6.48	2.73	5.23	5.60	3.33	5.29	1.80	.30	.72	.27	.11	.09	.18	T.	1.01	1.10	2.33	3.02	5.18	1.35	6.28	6.79	39.76	33.79
Fresno, Calif	1.73	3.64	1.43	2.07	1.58	2.36	.95	2.77	.44	T.	.08	.00	.01	T.	.01	T.	.21	.02	.57	1.17	.93	.80	1.45	1.16	9.39	13.99
Los Angeles, Calif	3.10	2.91	3.07	2.23	2.78	4.31	1.04	3.19	.45	.03	.08	T.	.01	T.	.02	.11	.17	T.	.68	.05	1.20	1.24	2.63	.42	15.23	14.49
Sacramento, Calif	3.72	4.81	3.02	1.97	2.57	2.93	1.51	5.81	.77	.01	.15	.00	.00	T.	.00	T.	.38	T.	.92	1.22	1.88	.77	3.03	2.18	17.95	19.70
San Diego, Calif	2.06	2.15	2.03	4.54	1.72	1.42	.77	1.02	.35	.02	.05	.00	.03	T.	.04	.18	.08	.01	.54	.05	.76	.07	1.87	.74	10.30	10.20
San Francisco, Calif	4.54	6.23	3.85	2.38	3.14	2.31	1.61	3.45	.80	.01	.18	T.	.02	T.	.01	.25	.45	.08	1.12	1.44	2.35	1.24	3.95	3.25	22.02	20.64

T.=Trace, indicates an amount too small to measure.

[1] Normals are based on records of 20 or more years of observations.

Weather Bureau.

TABLE 19.—*Frost: Dates of killing frosts, with length of growing season*

Station	Date of last killing frost in spring 1935	Date of first killing frost in fall 1935	Averages and extremes of killing frost for 30 to 51 years				
			Spring frosts		Fall frosts		Length of growing season between average dates of killing frosts
			Latest date	Average date	Earliest date	Average date of first	
							Days
Greenville, Maine	May 26[1]	Oct. 3[1]	June 23	May 30	Aug. 26	Sept. 14	107
Portland, Maine	Apr. 17	Oct. 25	June 20	Apr. 19	Sept. 11	Oct. 17	181
Concord, N. H	May 24[1]	Oct. 3	June 5	May 7	Sept. 6	Oct. 3	149
Northfield, Vt	May 24	Sept. 17	June 29	May 22	Aug. 26	Sept. 18	119
Boston, Mass	Apr. 18	Oct. 8	May 16	Apr. 14	Sept. 26	Oct. 26	195
Hartford, Conn	Apr. 17[1]	do	May 12	Apr. 20	Sept. 11	Oct. 14	177
Albany, N. Y	Apr. 16[1]	do	May 30	Apr. 24	Sept. 15	Oct. 15	174
Buffalo, N. Y	Apr. 18	Oct. 7	May 23	Apr. 28	Oct. 2	Oct. 22	177
Canton, N. Y	May 3	Sept. 28	June 2	May 4	Sept. 11	Sept. 30	149
Setauket, N. Y	Apr. 17[1]	Nov. 23[1]	May 17	Apr. 16	Oct. 21	Nov. 10	208
Syracuse, N. Y	do	Oct. 7	May 5	Apr. 23	Sept. 21	Oct. 22	182
Atlantic City, N. J	Apr. 16[1]	Nov. 19	Apr. 30	Apr. 10	Oct. 1	Nov. 5	209
Trenton, N. J	Apr. 5	Nov. 25	May 12	Apr. 16	Oct. 11	Oct. 24	191
Erie, Pa	Apr. 16	Oct. 8	May 17	Apr. 20	Oct. 8	Nov. 1	195
Harrisburg, Pa	do	do	May 12	Apr. 9	Oct. 3	Oct. 28	202
Pittsburgh, Pa	do	Oct. 7	May 29	Apr. 23	Sept. 19	Oct. 21	181
Scranton, Pa	do	Oct. 5	May 12	Apr. 21	Sept. 14	Oct. 14	176
Cincinnati, Ohio	Apr. 17	Oct. 7	Apr. 28	Apr. 8	Sept. 30	Oct. 23	198
Cleveland, Ohio	Apr. 17[1]	Nov. 21	May 21	Apr. 16	Oct. 2	Nov. 3	201
Columbus, Ohio	Apr. 17	Oct. 7	May 17	Apr. 18	Sept. 21	Oct. 19	184
Dayton, Ohio	Apr. 16	do	May 25	Apr. 19	Sept. 30	Oct. 20	184
Toledo, Ohio	Apr. 18	Oct. 4	May 29	Apr. 22	Sept. 9	Oct. 18	179
Evansville, Ind	Apr. 16[1]	Oct. 7	Apr. 26	Apr. 5	Oct. 7	Oct. 29	207
Fort Wayne, Ind	Apr. 16	Oct. 6	May 28	Apr. 25	Sept. 14	Oct. 13	171
Indianapolis, Ind	Apr. 17[1]	do	May 25	Apr. 16	Sept. 21	Oct. 20	187
Cairo, Ill	Mar. 9	Oct. 7	Apr. 30	Mar. 30	Sept. 30	Oct. 29	213
Chicago, Ill	Apr. 17[1]	Nov. 5	May 25	Apr. 16	Sept. 20	Oct. 19	186
Peoria, Ill	Apr. 16	Oct. 4	May 11	Apr. 15	Sept. 26	do	187
Springfield, Ill	Apr. 16[1]	do	May 25	do	Sept. 25	do	187
Alpena, Mich	May 15	Oct. 5	June 9	May 13	Sept. 6	Oct. 1	141
Detroit, Mich	Apr. 18	Sept. 28	May 31	Apr. 28	Sept. 21	Oct. 15	170
Grand Haven, Mich	May 6[1]	Oct. 6[1]	May 28	Apr. 30	Sept. 23	Oct. 18	171
Grand Rapids, Mich	May 4[1]	Oct. 6	May 30	May 1	do	do	170
Ludington, Mich	May 24	Oct. 5[1]	June 17	May 2	Sept. 4	Oct. 21	172
Marquette, Mich	May 14	Oct. 5	June 6	May 13	Aug. 23	Oct. 9	149
Green Bay, Wis	May 4	Oct. 4	May 30	May 5	Sept. 16	do	157
La Crosse, Wis	May 4[1]	do	May 24	Apr. 29	Sept. 10	do	163
Madison, Wis	May 4	do	May 25	Apr. 26	Sept. 16	Oct. 17	174
Milwaukee, Wis	do	do	May 29	do	Sept. 25	Oct. 18	175
Duluth, Minn	May 4[1]	Sept. 27	June 14	May 6	Sept. 10	Oct. 5	152
Minneapolis, Minn	May 2[1]	Oct. 4	May 20	Apr. 27	Sept. 13	Oct. 10	166
Moorhead, Minn	May 10	Sept. 27	June 8	May 12	Aug. 25	Sept. 24	135
Charles City, Iowa	May 4	do	May 21	Apr. 29	Sept. 12	Oct. 2	156
Des Moines, Iowa	Apr. 16	Oct. 4	May 31	Apr. 21	Sept. 13	Oct. 9	171
Dubuque, Iowa	May 4	do	May 21	Apr. 20	Sept. 26	Oct. 16	179
Keokuk, Iowa	Apr. 16[1]	do	May 4	Apr. 12	Sept. 18	Oct. 17	188
Columbia, Mo	Apr. 16	do	May 9	Apr. 13	do	Oct. 18	188
St. Joseph, Mo	Apr. 16[1]	Oct. 6[1]	Apr. 28	Apr. 26	Sept. 26	Oct. 17	191
St. Louis, Mo	Mar. 12	Oct. 6	May 22	Apr. 3	Sept. 30	Oct. 29	209
Springfield, Mo	Mar. 17	Nov. 5	May 19	Apr. 12	do	Oct. 22	193
Bismarck, N. Dak	Apr. 30	Sept. 26	June 7	May 11	Aug. 23	Sept. 21	133
Devils Lake, N. Dak	do	do	do	May 16	Aug. 8	Sept. 24	131
Williston, N. Dak	May 4	do	June 16	do	Aug. 22	Sept. 20	127
Huron, S. Dak	May 3[1]	Sept. 27	June 21	May 9	Aug. 23	Sept. 25	139
Pierre, S. Dak	Apr. 15	Sept. 27[1]	May 24	Apr. 30	Sept. 12	Oct. 7	160
Rapid City, S. Dak	May 3	Oct. 5	do	May 3	Sept. 13	Oct. 1	151
Yankton, S. Dak	May 5[1]	Sept. 27[1]	May 27	May 2	Sept. 14	Oct. 7	158
North Platte, Nebr	Apr. 15	Oct. 10	May 24	May 1	Sept. 10	Oct. 2	154
Omaha, Nebr	Apr. 16	Oct. 4	May 19	Apr. 14	Sept. 18	Oct. 15	184
Valentine, Nebr	May 4	Sept. 26	June 21	May 6	Sept. 12	Oct. 2	149
Concordia, Kans	Apr. 15	Oct. 24	May 19	Apr. 17	Sept. 27	Oct. 16	182
Dodge City, Kans	Apr. 7	Oct. 31	May 27	Apr. 16	Sept. 23	Oct. 21	188
Iola, Kans	Apr. 15[1]	Oct. 24	May 4	Apr. 7	Sept. 26	Oct. 17	193
Wichita, Kans	Mar. 17	Nov. 1	May 15	Apr. 9	Sept. 23	Oct. 23	197
Washington, D. C	Apr. 16	Nov. 24	May 12	Apr. 11	Oct. 2	Oct. 23	195
Lynchburg, Va	Apr. 16[1]	Oct. 10	May 7	Apr. 9	do	Oct. 27	201
Norfolk, Va	Mar. 1	Nov. 24	Apr. 26	Mar. 25	Oct. 11	Nov. 16	236
Richmond, Va	Mar. 15	Nov. 19	do	Mar. 31	Oct. 12	Nov. 2	216

[1] Temperature 32° F. or below.

TABLE 19.—*Frost: Dates of killing frosts, with length of growing season*—Contd.

Station	Date of last killing frost in spring 1935	Date of first killing frost in fall 1935	Averages and extremes of killing frost for 30 to 51 years: Spring frosts — Latest date	Spring frosts — Average date	Fall frosts — Earliest date	Fall frosts — Average date of first	Length of growing season between average dates of killing frosts
							Days
Wytheville, Va	Apr. 17	Oct. 5	May 27	Apr. 20	Sept. 19	Oct. 17	180
Elkins, W. Va	Apr. 16	do	June 1	May 4	Sept. 20	Oct. 12	161
Parkersburg, W. Va	Apr. 18	Oct. 4	May 22	Apr. 17	Sept. 29	Oct. 18	184
Asheville, N. C	Apr. 17[1]	Oct. 7	May 10	Apr. 11	Oct. 3	Oct. 22	194
Charlotte, N. C	Mar. 1	Nov. 24	Apr. 26	Mar. 25	Oct. 8	Nov. 5	225
Raleigh, N. C	do	do	do	Mar. 27	do	do	223
Wilmington, N. C	do	do	May 1	Mar. 21	Oct. 16	Nov. 15	239
Charleston, S. C	Jan. 29	Nov. 26	Apr. 2	Feb. 28	Oct. 28	Dec. 1	276
Columbia, S. C	Mar. 1	Nov. 24	Apr. 17	Mar. 17	Oct. 30	Nov. 18	246
Greenville, S. C	Mar. 13[1]	Nov. 23	Apr. 24	do	Oct. 10	Nov. 13	241
Atlanta, Ga	Mar. 13	do	Apr. 17	Mar. 29	Oct. 11	Nov. 8	224
Augusta, Ga	Mar. 1	Nov. 24	do	Mar. 15	Oct. 21	Nov. 12	242
Macon, Ga	do	do	Apr. 18	Mar. 14	Oct. 11	Nov. 14	245
Savannah, Ga	do	Nov. 25	Apr. 13	Feb. 26	Oct. 25	Nov. 23	270
Thomasville, Ga	do	Nov. 23[1]	Apr. 26	Mar. 8	do	Nov. 20	257
Apalachicola, Fla	Feb. 28[1]	None	Mar. 23	Feb. 5	Nov. 13	Dec. 28	326
Avon Park, Fla	Feb. 6[1]	Dec. 1[1]	Mar. 4	Jan. 12	Nov. 14	Dec. 26	348
Jacksonville, Fla	Mar. 1	Dec. 4	Apr. 10	Feb. 16	Nov. 12	Dec. 7	294
Miami, Fla	None	None	Mar. 3	(2)	Nov. 21	(2)	(2)
Tampa, Fla	Feb. 28	Dec. 27	Mar. 19	(2)	do	(2)	(2)
Chattanooga, Tenn	Mar. 1	Nov. 21	May 14	Mar. 29	Sept 30	Nov. 4	220
Knoxville, Tenn	Mar. 13[1]	do	Apr. 26	Apr. 2	Oct. 1	Oct. 29	210
Memphis, Tenn	Feb. 28	Nov. 23	Apr. 25	Mar. 21	Oct. 2	Nov. 4	228
Nashville, Tenn	Mar. 9	Oct. 7	Apr. 24	Mar. 31	Oct. 7	Oct. 28	211
Birmingham, Ala	Mar. 13	Nov. 24	Apr. 20	Mar. 17	Oct. 21	Nov. 10	238
Mobile, Ala	Mar. 1	Dec. 3	Apr. 6	Feb. 17	Oct. 31	Dec. 7	293
Montgomery, Ala	do	Nov. 24	Apr. 5	Mar. 8	Oct. 21	Nov. 13	250
New Orleans, La	Feb. 28[1]	Dec. 27[1]	Mar. 27	Jan. 25	Nov. 11	Dec. 18	327
Shreveport, La	do	Nov. 17	Apr. 9	Mar. 6	Oct. 20	Nov. 12	251
Abilene, Tex	Feb. 17	Nov. 11	Apr. 23	Mar. 23	Oct. 19	Nov. 9	231
Amarillo, Tex	Mar. 12	Nov. 4	May 23	Apr. 14	Oct. 16	Nov. 1	201
Brownsville, Tex	Feb. 27	None	Mar. 14	Jan. 25	Nov. 15	Dec. 23	332
Corpus Christi, Tex	do	do	Mar. 19	Feb. 15	Nov. 29	Dec. 20	308
Del Rio, Tex	Feb. 27[1]	do	Mar. 27	Feb. 23	Oct. 27	Nov. 27	277
El Paso, Tex	Mar. 12	Nov. 11	Apr. 26	Mar. 19	Oct. 23	Nov. 16	242
Fort Worth, Tex	Mar. 7[1]	Nov. 13	Apr. 9	Mar. 10	Oct. 22	do	251
Galveston, Tex	None	None	Mar. 19	Jan. 19	Nov. 16	Dec. 26	341
Palestine, Tex	Feb. 27[1]	Nov. 13	Apr. 5	Mar. 8	Oct. 20	Nov. 18	255
San Antonio, Tex	Feb. 27	None	do	Feb. 23	Oct. 30	Nov. 29	279
Taylor, Tex	Feb. 28[1]	Dec. 17[1]	do	Mar. 5	do	Nov. 26	266
Oklahoma City, Okla	Mar. 17[1]	Nov. 5	Apr. 30	Mar. 30	Oct. 7	Nov. 3	218
Fort Smith, Ark	Mar. 7	Nov. 20	Apr. 17	Mar. 23	Oct. 9	Nov. 6	228
Little Rock, Ark	Feb. 28	Nov. 23	Apr. 26	Mar. 18	Oct. 22	Nov. 14	241
Havre, Mont	May 9	Sept. 26	June 6	May 14	Aug. 25	Sept. 20	129
Helena, Mont	May 8	Sept. 27	June 9	May 7	do	Sept. 29	145
Kalispell, Mont	Apr. 28	Sept. 27[1]	June 7	May 10	Sept. 6	Sept. 30	143
Miles City, Mont	Apr. 29	Oct. 22	May 31	May 5	Sept. 7	Oct. 2	150
Cheyenne, Wyo	May 4	Oct. 21	June 13	May 18	Aug. 25	Sept. 22	127
Lander, Wyo	May 15	Sept. 28	June 20	do	Aug. 23	Sept. 18	123
Sheridan, Wyo	May 9	Oct. 10	June 6	May 20	Aug. 25	Sept. 20	123
Yellowstone Park, Wyo	June 3[1]	Sept. 27	June 22	May 21	do	Sept. 16	118
Denver, Colo	May 4[1]	Oct. 22	June 6	May 3	Sept. 12	Oct. 10	160
Grand Junction, Colo	Apr. 11	Oct. 17	May 14	Apr. 16	Sept. 14	Oct. 19	186
Pueblo, Colo	May 4[1]	Oct. 25	June 2	Apr. 24	Sept. 12	Oct. 10	169
Roswell, N. Mex	Mar. 12	Nov. 5	May 7	Apr. 10	Oct. 10	Oct. 28	201
Santa Fe, N. Mex	May 5[1]	Oct. 25	May 23	Apr. 25	Sept. 25	Oct. 19	177
Flagstaff, Ariz	June 1[1]	Sept. 28	June 17	May 31	Sept. 12	Sept. 24	116
Phoenix, Ariz	Jan. 22	None	Mar. 31	Feb. 10	Nov. 5	Dec. 3	296
Tucson, Ariz	Mar. 11	Nov. 4[1]	Apr. 18	Mar. 11	Oct. 19	Nov. 20	248
Yuma, Ariz	None	None	Mar. 15	Jan. 20	Nov. 19	Dec. 20	334
Modena, Utah	Apr. 9	Oct. 17	July 3	May 21	Sept. 5	Sept. 29	131
Salt Lake City, Utah	Apr. 24[1]	do	June 18	Apr. 18	Sept. 22	Oct. 20	185
Reno, Nev	Apr. 18[1]	do	June 13	May 14	Sept. 6	Oct. 6	145
Winnemucca, Nev	May 18	Oct. 13	June 22	do	Aug. 22	Sept. 27	136
Boise, Idaho	Mar. 27	Oct. 20	June 16	Apr. 27	Sept. 11	Oct. 12	168
Lewiston, Idaho	Apr. 14[1]	Oct. 21[1]	May 10	Apr. 6	Sept. 21	Oct. 24	201
Pocatello, Idaho	Apr. 25	Oct. 23	June 1	Apr 29	Sept. 8	Oct. 6	160
Seattle, Wash	Mar. 2[1]	Oct. 29	May 10	Mar. 16	Oct. 18	Nov. 22	251

[1] Temperature 32° F, or below.
[2] Frosts do not occur every year.

Station	Date of last killing frost in spring 1935	Date of first killing frost in fall 1935	Averages and extremes of killing frost for 30 to 51 years				
			Spring frosts		Fall frosts		Length of growing season between average dates of killing frosts
			Latest date	Average date	Earliest date	Average date of first	
							Days
Spokane, Wash	Apr. 28[1]	Oct. 21	June 8	Apr. 14	Sept. 7	Oct. 13	182
Walla Walla, Wash	Apr. 3	Oct. 23	May 9	Mar. 31	Sept. 24	Nov. 4	218
Baker, Oreg	May 11	Oct. 20	June 23	May 17	Aug. 30	Sept. 29	135
Portland, Oreg	Mar. 9[1]	Oct. 30	May 2	Mar. 15	Oct. 13	Nov. 21	251
Roseburg, Oreg	Mar. 31[1]	Nov. 1[1]	May 24	Apr. 8	Sept. 24	Nov. 11	217
Eureka, Calif	None	Nov. 3	Apr. 7	Mar. 16	Nov. 3	Dec. 18	277
Fresno, Calif	Jan. 20	Oct. 31	Apr. 14	Feb. 22	Oct. 31	Nov. 30	281
Independence, Calif	Apr. 9	Oct. 23	May 24	Apr. 13	Sept. 24	Oct. 27	197
Los Angeles, Calif	None	None	Feb. 17	(2)	Nov. 2	(2)	(2)
Red Bluff, Calif	Apr. 9[1]	Oct. 30[1]	May 9	Mar. 8	Nov. 5	Dec. 5	272
Sacramento, Calif	Jan. 20	Nov. 4	May 7	Feb. 19	Nov. 4	Nov. 29	283
San Bernardino, Calif	Apr. 10[1]	Oct. 31[1]	Apr. 23	Mar. 8	Oct. 23	Nov. 22	259
San Diego, Calif	None	None	Jan. 20	(2)	Dec. 26	(2)	(2)
San Francisco, Calif	do	do	Mar. 26	Jan. 13	Dec. 4	Dec. 29	350

[1] Temperature 32° F. or below.   [2] Frosts do not occur every year.

Weather Bureau.

TABLE 20.—*Monthly and annual rainfall by States, 1935*

State	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Alabama	2.51	4.41	7.30	5.50	4.39	3.70	4.74	5.09	2.35	1.71	3.17	4.24	49.11
Arizona	1.81	2.22	1.50	.43	.46	.08	1.29	3.85	1.51	.05	1.13	.79	15.12
Arkansas	5.79	2.44	8.29	4.37	8.86	8.38	2.32	1.74	3.13	4.94	3.81	2.95	57.02
California	5.37	2.52	3.91	4.70	.23	.01	.07	.34	.15	1.20	1.09	2.46	22.05
Colorado	.78	.57	1.00	2.05	3.74	.82	1.52	1.77	1.93	.80	.47	.36	15.81
Connecticut	4.90	3.20	2.30	2.39	1.93	5.16	4.57	1.27	4.14	.72	4.12	1.05	35.75
Delaware	5.49	3.30	3.25	3.81	3.60	5.16	4.33	3.66	10.97	2.92	5.34	2.61	54.44
Florida	1.40	2.50	.99	4.17	3.66	5.17	9.11	8.85	9.57	2.63	1.54	2.73	52.32
Georgia	2.97	3.50	4.59	4.58	2.91	2.72	6.87	5.59	3.64	1.10	3.75	2.75	44.97
Idaho	1.98	.72	1.72	2.30	1.23	.50	.31	.22	.22	.93	.91	1.36	12.40
Illinois	2.44	1.47	4.64	2.62	7.78	5.99	3.33	2.59	3.25	2.05	4.59	1.22	41.97
Indiana	2.79	1.00	5.05	2.44	7.01	4.75	3.57	3.12	2.62	1.84	3.52	1.61	39.32
Iowa	1.16	1.13	1.47	1.92	4.84	7.00	3.35	2.42	3.46	2.76	2.70	.95	33.16
Kansas	.61	.79	.82	1.13	7.78	5.08	.68	2.95	3.17	2.88	2.31	.27	28.47
Kentucky	5.28	2.35	9.56	4.42	7.40	7.50	5.16	4.22	2.75	2.51	3.86	2.39	57.40
Louisiana	3.53	4.44	6.43	6.00	7.81	4.70	5.24	4.43	3.92	1.33	3.42	5.72	56.97
Maine	6.72	2.18	1.61	3.18	1.94	5.17	3.07	2.28	4.16	1.03	4.93	1.91	38.18
Maryland	4.67	2.63	2.99	3.76	3.64	4.49	4.23	3.22	7.60	2.75	4.32	2.49	46.79
Massachusetts	6.07	3.03	1.92	3.79	2.19	5.75	3.28	1.68	4.35	1.01	5.09	1.25	39.41
Michigan	1.98	1.45	1.93	1.33	2.70	4.03	2.57	3.64	2.48	1.69	3.46	1.38	28.64
Minnesota	1.22	.28	1.52	2.38	2.39	4.76	3.82	4.52	1.32	1.81	1.07	.78	25.87
Mississippi	4.76	3.53	8.33	6.22	5.93	4.10	3.20	2.71	2.60	2.70	3.55	3.90	51.53
Missouri	2.42	1.55	5.27	2.89	8.50	9.25	3.12	2.26	3.63	3.52	4.11	1.13	47.65
Montana	.87	.19	1.28	1.12	1.66	1.49	1.63	.62	.30	.81	.55	.37	10.89
Nebraska	.20	.63	.78	3.33	6.24	3.73	1.34	2.68	1.68	.83	1.01	.29	22.74
Nevada	1.09	.96	.85	1.88	1.18	.02	.18	.38	.16	.39	.66	.87	8.62
New Hampshire	6.01	2.49	1.66	2.78	2.28	6.10	3.30	2.28	5.15	1.18	4.65	1.25	39.13
New Jersey	4.00	2.80	2.46	2.27	1.71	4.64	4.66	2.57	6.12	4.50	4.95	1.67	42.32
New Mexico	.85	.73	.39	.56	2.35	.84	1.34	3.53	2.28	.40	1.05	.50	14.82
New York	3.67	2.24	2.05	2.74	2.53	4.45	6.37	2.26	3.59	2.75	3.44	1.85	37.94
North Carolina	4.15	2.80	5.01	4.13	3.47	2.29	7.42	5.13	5.30	1.49	3.89	3.00	48.08
North Dakota	.41	.21	1.02	1.94	2.66	3.01	4.62	2.34	.44	.16	.75	.51	18.07

TABLE 20.—*Monthly and annual rainfall by States, 1935*—Continued

State	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Ohio	2.62	1.79	3.35	1.95	4.88	3.96	4.93	6.06	2.88	2.03	2.62	2.47	39.54
Oklahoma	1.31	1.07	3.86	2.28	7.48	6.67	.94	2.66	2.81	3.12	2.75	1.77	36.72
Oregon	3.13	1.93	2.98	2.90	.64	.78	.56	.20	.50	2.06	1.62	3.12	20.42
Pennsylvania	3.08	2.67	2.62	2.56	3.00	4.22	5.63	3.91	3.51	2.77	3.84	2.62	40.43
Rhode Island	6.37	2.98	1.68	3.70	1.64	4.79	3.98	1.48	3.98	1.00	4.98	1.16	37.74
South Carolina	2.68	2.67	2.62	3.60	2.58	2.25	7.34	6.67	5.38	1.12	3.11	2.82	42.84
South Dakota	.24	.57	1.27	3.57	2.85	2.97	2.02	1.80	.45	.24	.53	.56	17.07
Tennessee	5.84	3.91	7.77	4.82	4.78	4.74	3.73	2.96	1.72	3.12	4.65	1.69	49.73
Texas	1.49	2.25	1.82	2.57	7.20	5.07	2.31	1.54	5.77	2.34	1.94	3.18	37.48
Utah	.73	.91	1.41	2.05	2.11	.05	.43	.95	.43	.27	.69	.80	10.83
Vermont	4.91	2.14	1.63	2.53	2.34	5.43	5.38	2.52	4.37	1.29	4.65	1.20	38.39
Virginia	4.78	2.59	4.95	4.26	3.69	3.48	5.04	3.86	5.48	2.24	4.02	2.31	46.70
Washington	7.58	2.43	4.29	1.45	.59	1.53	.84	.60	1.30	2.25	2.27	4.10	29.23
West Virginia	4.48	2.33	5.51	3.45	6.07	5.20	4.61	6.71	3.30	3.01	2.80	3.66	51.13
Wisconsin	1.89	.92	1.32	2.43	2.52	5.12	4.24	4.12	2.39	2.48	2.04	.91	30.38
Wyoming	.36	.51	.97	1.93	3.68	1.02	.73	.78	.65	.53	.63	.49	12.28

Weather Bureau.

TABLE 21.—*National-forest areas, by regions, June 30, 1935*

Region No.	Name of region	Region headquarters	Gross area	Alienated lands	Net area
			Acres	*Acres*	*Acres*
1	Northern	Missoula, Mont	26,651,296	3,787,792	22,863,504
2	Rocky Mountain	Denver, Colo	21,200,646	1,826,671	19,373,975
3	Southwestern	Albuquerque, N. Mex	21,999,988	2,073,488	19,926,500
4	Intermountain	Ogden, Utah	30,862,188	1,645,000	29,217,188
5	California	San Francisco, Calif	24,210,502	4,869,485	19,341,017
6	North Pacific	Portland, Oreg	27,041,094	3,826,826	23,214,268
7	Eastern	Washington, D. C	3,605,727	1,698,129	1,907,598
8	Southern	Atlanta, Ga	6,799,717	3,198,472	3,601,245
9	North Central	Milwaukee, Wis	4,523,977	2,001,871	2,522,106
10	Alaska	Juneau, Alaska	21,397,082	54,481	21,342,601
	Total		188,292,217	24,982,215	163,310,002

Headquarters of national forests:

Region 1: Federal Building, Missoula, Mont.; embracing Montana, northeastern Washington, northern Idaho, and northwestern South Dakota.

Region 2: Post Office Building, Denver, Colo.; embracing Colorado, eastern Wyoming, South Dakota, Nebraska, and western Oklahoma.

Region 3: Federal Building, Albuquerque, N. Mex.; embracing Arizona and New Mexico.

Region 4: Forest Service Building, Ogden, Utah.; embracing Utah, southern Idaho, western Wyoming, and Nevada.

Region 5: Phelan Building, San Francisco, Calif.; embracing California and southwestern Nevada.

Region 6: Post Office Building, Portland, Oreg.; embracing Washington and Oregon.

Region 7: Victor Building, Washington, D. C.; embracing Kentucky, Maine, New Hampshire, Pennsylvania, Puerto Rico, Vermont, Virginia, and West Virginia.

Region 8: Glenn Building, Atlanta, Ga.; embracing Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, eastern Oklahoma, South Carolina, Tennessee, Texas, and portion of Virginia.

Region 9: Federal Building, Milwaukee, Wis.; embracing Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, North Dakota, Ohio, and Wisconsin.

Region 10: Federal and Territorial Building, Juneau, Alaska; located in Alaska.

Forest Service. See 1931 Yearbook, table 554, for lists of national monuments, national game refuges, and range reserves. Later information can be had from the Forest Service, Washington, D. C.

TABLE 22.—*Mileage of roads under State control, including Federal-aid system, at the end of 1934, as reported by State highway departments*

PRIMARY STATE SYSTEMS

State	Total system mileage	Earth nonsurfaced		Surfaced roads by types								
		Unimproved	Improved to grade	Total surfaced mileage	Sand-clay, top-soil	Gravel, chert, etc.	Water-bound macadam, treated and untreated	Low-cost bituminous mix	Bituminous macadam	Bituminous concrete	Portland-cement concrete	Brick and block (1)
	Miles	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*
Alabama	6,253	1,652	653	3,948	1,057	1,655	17	54	159	135	871	------
Arizona	2,994	368	267	2,359	------	2,138	------	------	23	54	144	------
Arkansas	8,864	551	901	7,412	------	5,428	------	386	132	438	1,028	------
California	12,631	1,249	259	11,123	2,248	982	------	2,094	1,942	1,351	2,438	68
Colorado	3,559	------	626	2,933	------	2,443	------	2	4	------	484	------
Connecticut	2,317	------	88	2,229	------	219	956	------	330	130	593	1
Delaware	1,225	------	------	1,225	54	295	------	------	46	40	785	5
Florida	10,708	1,401	2,676	6,631	773	180	4,266	288	51	336	552	185
Georgia	9,031	3,329	668	5,034	1,052	422	1,304	------	419	365	1,439	33
Idaho	4,762	963	477	3,322	53	1,522	------	1,554	26	115	50	2
Illinois	10,099	231	16	9,852	------	11	1	5	------	25	9,549	261
Indiana	9,292	774	32	8,486	124	2,495	53	1,283	182	454	3,792	103
Iowa	7,910	165	175	7,570	------	2,933	------	324	------	------	4,284	29
Kansas	8,513	1,815	547	6,151	2,727	340	------	1,656	187	2	1,082	157
Kentucky	7,538	------	768	6,770	------	3,651	1,024	468	202	439	980	6
Louisiana	4,446	41	94	4,311	------	2,278	------	------	------	76	1,957	------
Maine	2,314	70	------	2,244	------	1,612	------	------	390	7	234	1
Maryland	3,855	------	------	3,855	------	656	1,105	------	217	259	1,616	2
Massachusetts	1,833	------	------	1,833	------	47	120	4	1,014	257	387	4
Michigan	8,256	365	68	7,823	87	3,575	294	139	64	271	3,387	6
Minnesota	11,208	433	180	10,595	242	7,512	65	87	------	164	2,370	155
Mississippi	3,980	28	144	3,808	15	3,007	------	129	11	60	574	12
Missouri	8,082	110	101	7,871	------	2,702	------	1,370	235	90	3,467	7
Montana	5,145	1,100	193	3,852	87	1,868	------	1,810	16	24	46	1
Nebraska	9,179	1,671	630	6,878	------	5,602	------	488	------	11	734	43
Nevada	2,612	332	6	2,274	------	786	------	1,439	------	29	20	------
New Hampshire	1,460	------	------	1,460	------	957	61	------	159	36	247	------
New Jersey	1,351	63	19	1,269	------	48	53	------	5	87	1,059	17
New Mexico	10,185	5,328	1,423	3,434	------	2,293	------	1,033	1	38	69	------
New York	13,946	1,513	23	12,410	------	195	847	1,123	2,687	922	6,452	184
North Carolina	10,330	251	633	9,446	3,485	1,438	12	663	109	1,065	2,647	27
North Dakota	7,603	651	1,036	5,916	------	5,484	------	394	------	5	33	------
Ohio	12,204	46	14	12,144	------	4,391	1,050	------	1,662	779	2,808	1,454
Oklahoma	7,440	1,026	413	6,001	------	3,426	------	53	------	722	1,755	45
Oregon	4,625	215	371	4,039	------	------	2,477	------	798	544	220	------
Pennsylvania	12,974	------	964	12,010	5	3,465	1,139	694	408	517	5,616	166
Rhode Island	1,010	160	186	664	------	104	86	------	233	81	160	------
South Carolina	5,998	359	110	5,529	2,819	336	------	------	------	445	1,927	2
South Dakota	5,989	374	601	5,014	20	4,256	------	522	------	5	211	------
Tennessee	7,188	222	333	6,633	------	2,869	1,047	97	562	614	1,424	20
Texas	20,012	2,986	2,692	14,834	6	6,493	1,441	620	------	1,752	3,970	52
Utah	3,599	416	948	2,235	------	986	------	1,004	4	46	195	------
Vermont	1,029	------	10	1,019	------	398	------	206	134	1	280	------
Virginia	9,044	985	208	7,851	814	3,803	1,671	------	751	80	732	------
Washington	3,799	170	57	3,572	------	517	------	1,709	178	71	1,054	43
West Virginia	4,514	308	299	3,907	------	1,046	318	422	685	313	992	131
Wisconsin	9,992	------	461	9,531	47	4,288	472	285	185	53	4,195	6
Wyoming	8,414	348	259	2,807	57	848	------	1,867	------	27	8	------
Total	324,312	32,069	20,629	271,614	15,772	102,000	19,879	24,272	14,211	13,335	78,917	3,228
SECONDARY ROADS UNDER STATE CONTROL												
Colorado	5,769	170	3,220	2,379	------	2,379	------	------	------	------	------	------
Louisiana	12,993	5,353	273	7,367	------	7,365	------	2	------	------	------	------
Maine	5,669	1,335	16	4,318	------	4,250	------	------	35	2	20	11
Mississippi	2,088	17	14	2,057	------	1,980	------	12	------	------	65	------
Missouri	4,380	------	712	3,668	------	3,477	------	58	19	11	103	------
Montana	274	------	------	274	------	194	------	80	------	------	------	------
Nevada	1,371	1,333	15	23	------	16	------	7	------	------	------	------
New Hampshire	1,603	5	32	1,566	------	1,513	31	1	11	3	7	------
North Carolina	47,066	10,361	20,759	15,946	13,776	1,669	------	------	136	146	176	43
Oregon	2,046	350	232	1,464	------	------	1,313	------	10	103	38	------
Pennsylvania	20,257	------	5,982	14,275	------	9,332	259	3,839	186	159	388	112
Utah	655	172	170	313	------	251	------	26	------	12	24	------
Virginia	36,953	12,155	8,257	16,541	3,233	13,308	------	------	------	------	------	------
West Virginia	29,120	22,260	2,601	4,259	------	2,110	886	917	------	------	346	------
Total	170,244	53,511	42,283	74,450	17,009	47,844	2,489	4,942	397	436	1,167	166
Grand total [2]	494,556	85,580	62,912	346,064	32,781	149,844	22,368	29,214	14,608	13,771	80,084	3,394

[1] Includes timber bridge flooring.

[2] Includes secondary roads under State control.

Bureau of Public Roads.

TABLE 23.—*Motor-vehicle registrations and revenues, by States, 1934, and totals for 1925–33, as reported by State authorities*

State	Registered motor vehicles			Gross registration receipts of calendar year	Disposition of gross receipts [1]			
	All motor cars and trucks	Passenger autos, taxicabs and busses	Motor-trucks and road tractors		Collection costs	Construction, maintenance, etc.		Miscellaneous [3]
						State highways [2]	Local roads and streets [3]	
	Number	*Number*	*Number*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*
Alabama	225, 732	191, 631	34, 101	3, 584	264	2, 631	-------	689
Arizona	96, 586	79, 795	16, 791	759	139	605	-------	-------
Arkansas	198, 091	162, 391	35, 700	2, 233	71	2, 102	-------	60
California	2, 006, 255	1, 768, 699	237, 556	9, 561	1, 798	4, 833	2, 722	6
Colorado	274, 231	246, 373	27, 858	2, 149	243	-------	798	1, 107
Connecticut	351, 405	295, 517	55, 888	7, 948	748	3, 591	3, 126	-------
Delaware	54, 240	44, 846	9, 394	967	-------	967	-------	-------
Florida	335, 205	279, 846	55, 359	4, 466	315	-------	-------	4, 138
Georgia	376, 993	316, 731	60, 262	1, 193	148	1, 011	-------	39
Idaho	108, 863	91, 002	17, 861	1, 561	78	146	1, 339	-------
Illinois	1, 456, 241	1, 281, 976	174, 265	18, 284	1, 158	15, 422	2, 108	443
Indiana	803, 271	680, 480	122, 791	7, 285	758	3, 148	1, 471	1, 919
Iowa	666, 440	591, 090	75, 350	9, 476	645	8, 665	-------	-------
Kansas	528, 664	453, 099	75, 565	3, 278	217	2, 125	950	-------
Kentucky	332, 177	294, 732	37, 445	3, 145	391	2, 306	405	-------
Louisiana	244, 007	199, 228	44, 779	4, 380	137	4, 024	175	-------
Maine	178, 995	141, 302	37, 693	3, 096	90	2, 653	341	12
Maryland	332, 892	287, 541	45, 351	4, 188	371	2, 945	838	34
Massachusetts	785, 392	686, 884	98, 508	7, 071	1, 362	2, 318	2, 933	458
Michigan	1, 148, 953	1, 025, 548	123, 405	15, 901	848	100	13, 980	785
Minnesota	697, 672	593, 790	103, 882	6, 867	485	5, 982	-------	414
Mississippi	174, 934	140, 819	34, 115	1, 950	96	172	1, 683	-------
Missouri	739, 813	632, 104	107, 709	7, 374	470	6, 905	-------	-------
Montana	128, 336	97, 249	31, 087	1, 071	135	-------	936	-------
Nebraska	406, 632	350, 072	56, 560	1, 896	79	560	1, 274	-------
Nevada	32, 230	25, 839	6, 391	248	18	229	-------	-------
New Hampshire	113, 134	90, 752	22, 382	2, 470	105	2, 342	23	-------
New Jersey	864, 641	741, 290	123, 351	15, 614	750	8, 731	6, 072	61
New Mexico	82, 900	66, 788	16, 112	843	104	336	111	297
New York	2, 269, 355	1, 970, 976	298, 379	41, 629	2, 266	11, 809	8, 936	18, 618
North Carolina	439, 351	384, 585	54, 766	7, 114	245	6, 576	-------	293
North Dakota	156, 203	129, 888	26, 315	1, 299	84	100	-------	1, 100
Ohio	1, 613, 265	1, 453, 420	159, 845	20, 273	942	3, 693	15, 332	338
Oklahoma	477, 292	403, 364	73, 928	3, 251	369	1, 210	1, 730	-------
Oregon	274, 117	232, 706	41, 411	2, 249	276	1, 577	314	2
Pennsylvania	1, 681, 202	1, 466, 186	215, 016	32, 795	1, 533	28, 870	289	163
Rhode Island	142, 394	124, 062	18, 332	2, 279	262	1, 590	-------	427
South Carolina	202, 834	181, 957	20, 877	2, 213	181	2, 032	-------	-------
South Dakota	169, 975	146, 143	23, 832	1, 314	45	251	1, 010	11
Tennessee	336, 313	298, 558	37, 755	3, 441	182	2, 754	-------	490
Texas	1, 312, 152	1, 085, 876	226, 276	14, 720	857	4, 605	9, 259	-------
Utah	101, 926	84, 823	17, 103	966	98	675	-------	-------
Vermont	77, 921	69, 309	8, 612	2, 157	110	783	1, 150	-------
Virginia	373, 908	316, 640	57, 268	4, 949	323	4, 790	-------	8
Washington	422, 238	357, 917	64, 321	3, 068	307	2, 371	73	317
West Virginia	223, 155	192, 067	31, 088	5, 624	48	5, 576	-------	-------
Wisconsin	709, 359	589, 179	120, 180	10, 051	642	7, 061	2, 535	1, 472
Wyoming	64, 990	51, 888	13, 102	449	10	439	-------	-------
District of Columbia	163, 070	145, 807	17, 263	605	84	-------	-------	521
Total, 1934	24, 955, 945	21, 542, 765	3, 413, 180	309, 304	20, 887	171, 617	81, 913	34, 222
Total:								
1933	23, 827, 288	20, 600, 542	3, 226, 746	301, 315	23, 316	119, 618	61, 379	97, 002
1932	24, 114, 977	20, 883, 625	3, 231, 352	324, 274	17, 551	155, 912	75, 964	74, 847
1931	25, 814, 103	22, 348, 023	3, 466, 080	344, 338	19, 689	200, 734	70, 043	53, 872
1930	26, 545, 281	23, 059, 262	3, 486, 019	355, 705	19, 197	222, 147	68, 578	45, 783
1929	26, 501, 443	23, 121, 589	3, 379, 854	347, 844	17, 403	223, 293	66, 861	40, 287
1928	24, 493, 124	21, 379, 125	3, 113, 999	322, 630	15, 134	208, 880	60, 399	38, 217
1927	23, 133, 241	20, 219, 223	2, 914, 018	301, 061	14, 876	189, 985	53, 578	42, 622
1926	22, 001, 393	19, 237, 171	2, 764, 222	288, 282	16, 602	191, 111	51, 702	28, 867
1925	19, 937, 274	17, 496, 420	2, 440, 854	260, 620	11, 993	177, 707	48, 396	22, 524

[1] In a number of cases the total amounts distributed do not equal the gross registration receipts of calendar year. Differences are due to changes in undistributed balances carried over and other reconciling adjustments.
[2] Includes service of highway obligations.
[3] Figures in this column for 1925–33 include service of highway obligations.

Bureau of Public Roads.

Table 24.—*Gasoline taxes, by States, 1934, and totals for 1925–33, as reported by State authorities*

State	Total tax (refunds deducted)	Disposition of total taxes collected [1]: Collection costs	Construction, etc.: State highways	Construction, etc.: Local roads and streets	State and county road bond payments	Miscellaneous	Net gallons taxed	Tax rate per gallon
	1,000 dollars	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 gallons*	*Cents*
Alabama	9,226	14	2,204	4,601	2,407	----------	154,977	6
Arizona	3,024	40	1,775	907	----------	302	60,565	5
Arkansas	7,777	269	2,529	966	4,251	189	125,576	6½
California	36,442	139	24,161	12,080	----------	----------	1,198,655	3
Colorado	6,445	83	3,151	1,508	----------	1,719	143,290	4
Connecticut	4,849	34	4,671	----------	----------	----------	248,658	2
Delaware	1,187	----------	917	----------	270	----------	39,514	3
Florida	16,290	17	6,982	----------	6,967	2,331	235,698	7
Georgia	14,305	413	9,205	2,301	----------	2,386	239,435	6
Idaho	2,853	11	2,517	88	214	7	57,553	5
Illinois	29,215	149	7,951	13,128	----------	8,115	970,874	3
Indiana	17,346	73	8,652	8,651	----------	----------	438,743	4
Iowa	11,027	88	2,537	4,806	3,557	----------	374,998	3
Kansas	8,547	281	4,930	2,516	699	78	283,876	3
Kentucky	9,055	42	9,007	----------	----------	3	184,369	5
Louisiana	8,910	61	----------	----------	6,541	1,782	178,457	5
Maine	4,478	12	2,852	509	1,106	----------	115,794	4
Maryland	8,291	17	2,060	3,775	2,316	123	195,663	4
Massachusetts	16,952	50	2,565	3,568	255	10,515	566,735	3
Michigan	20,848	145	9,902	6,773	4,082	22	699,830	3
Minnesota	10,845	----------	6,381	3,651	----------	----------	361,512	3
Mississippi	6,860	29	3,630	2,846	----------	355	125,429	6
Missouri	9,681	49	5,222	----------	4,303	98	478,764	2
Montana	3,596	20	2,384	----------	1,044	----------	73,271	5
Nebraska	8,649	66	5,314	3,187	----------	86	214,257	4
Nevada	891	----------	863	----------	28	----------	22,355	4
New Hampshire	2,796	----------	2,069	----------	727	----------	68,641	4
New Jersey	16,788	48	7,265	2,377	8,297	4,177	567,839	3
New Mexico	2,556	41	1,089	----------	1,617	----------	51,134	5
New York	43,628	91	5,152	7,949	3,627	26,808	1,464,242	3
North Carolina	17,050	6	9,007	----------	6,635	1,402	279,797	6
North Dakota	2,219	25	1,358	730	102	----------	75,390	3
Ohio	37,657	177	15,336	11,479	----------	10,215	1,031,157	4
Oklahoma	10,821	216	5,155	2,651	----------	3,181	270,432	4
Oregon	7,215	22	3,445	1,187	2,525	15	145,514	5
Pennsylvania	33,356	235	22,376	2,727	3,088	144	1,113,629	3
Rhode Island	2,032	----------	1,444	----------	302	286	102,834	2
South Carolina	7,746	----------	750	1,291	5,694	----------	128,646	6
South Dakota	3,784	38	1,681	----------	----------	1,980	98,997	4
Tennessee	14,104	143	2,705	3,989	4,245	2,781	201,627	7
Texas	31,937	224	15,774	----------	7,887	7,887	791,005	4
Utah	2,489	----------	2,700	----------	----------	14	62,858	4
Vermont	1,942	----------	416	1,091	327	----------	48,550	4
Virginia	12,497	164	11,823	203	264	53	249,540	5
Washington	11,882	20	4,850	6,064	----------	948	239,187	5
West Virginia	5,613	13	2,936	----------	2,664	----------	142,393	4
Wisconsin	15,405	46	8,709	3,879	2,112	3,199	384,981	4
Wyoming	1,768	8	1,188	414	112	25	'4,111	4
District of Columbia	2,132	----------	----------	1,925	----------	----------	103,129	2
Total, 1934	565,006	3,619	259,590	123,817	88,265	91,226	15,454,481	3.66
Total:								
1933	519,403	2,728	277,517	111,109	58,973	69,076	14,224,321	3.65
1932	514,139	2,833	301,788	94,074	50,726	64,718	14,250,173	3.60
1931	537,589	2,117	354,017	100,074	42,488	38,893	15,407,650	3.48
1930	494,683	1,102	338,927	96,226	31,049	27,379	14,751,309	3.35
1929	431,636	778	207,968	85,113	23,372	24,405	13,400,180	3.22
1928	305,234	695	211,046	57,381	17,620	18,492	10,178,345	3.00
1927	258,967	500	182,096	55,440	10,086	10,845	9,366,652	2.76
1926	187,603	239	129,442	43,609	5,239	9,074	7,883,984	2.38
1925	146,029	217	98,605	31,849	4,333	11,025	6,457,783	2.26

[1] In a number of cases the total amounts distributed do not equal the total tax. Differences are due to changes in undistributed balances carried over, and other reconciling adjustments.

Bureau of Public Roads.

TABLE 25.—*Freight tonnage originating on railways in the United States, 1928–34* [1]

Commodity	Calendar year						
	1928	1929	1930	1931	1932	1933	1934 [2]
FARM PRODUCTS							
Animal and animal products:	*1,000 short tons*	*1,000 short tons*	*1,000 short tons*	*1,000 short tons*	*1,000 short tons*	*1,000 short tons*	*1,000 short tons*
Animals live:							
Horses and mules	577	553	440	316	230	281	355
Cattle and calves	7,976	7,310	6,785	6,097	4,896	4,496	7,279
Sheep and goats	1,362	1,387	1,385	1,343	1,085	1,008	1,059
Hogs	5,871	5,534	4,902	4,501	3,885	3,608	3,004
Packing-house products:							
Fresh meats	2,935	3,007	2,928	2,933	2,724	2,951	3,229
Hides and leather	914	913	847	782	655	734	790
Other packing-house products	1,461	1,414	1,165	1,140	1,052	992	883
Total	5,310	5,334	4,940	4,855	4,431	4,677	4,902
Eggs	635	588	612	582	424	422	403
Butter and cheese	754	793	807	768	735	756	772
Poultry	407	418	419	416	382	402	377
Wool	394	414	354	388	271	336	237
Other animals and products	2,348	2,576	2,485	2,366	1,716	1,665	1,975
Total animals and animal products	25,634	24,907	23,129	21,632	18,055	17,651	20,363
Vegetable products:							
Cotton	3,772	3,940	3,032	2,432	2,777	3,374	2,503
Fruits and vegetables	12,947	12,875	12,589	11,906	9,866	8,925	9,413
Potatoes	4,511	4,425	4,332	4,114	3,418	3,466	3,804
Grain and grain products:							
Grain:							
Wheat	26,950	27,019	25,466	26,228	19,120	16,501	16,018
Corn	17,045	15,258	13,986	10,728	9,544	12,310	11,427
Oats	5,888	5,713	5,184	3,970	3,399	3,353	2,501
Other grain	5,506	4,477	4,045	2,924	2,229	2,995	3,213
Grain products:							
Flour and meal	10,754	10,627	10,546	10,067	9,319	8,998	8,932
Other mill products	10,580	10,821	10,610	8,783	6,629	6,779	7,095
Total	76,723	73,915	69,837	62,700	50,240	50,936	49,186
Hay, straw, and alfalfa	3,999	3,697	3,494	2,174	1,569	1,476	2,563
Sugar, sirup, glucose, and molasses	5,604	5,858	5,659	5,142	4,286	4,779	5,059
Tobacco	945	989	1,008	816	642	680	679
Other vegetable products	16,686	15,502	16,436	13,346	12,405	12,845	11,158
Total vegetable products	125,187	121,201	116,387	102,630	85,203	86,481	84,365
Canned goods (food products)	4,805	5,029	4,751	3,954	3,167	3,308	3,816
Total farm products	155,626	151,137	144,267	128,216	106,425	107,440	108,544
OTHER FREIGHT							
Products of mines	696,583	737,879	642,537	501,903	362,226	395,065	436,380
Products of forests	96,737	94,855	69,366	43,024	26,109	33,165	35,650
Manufactures	300,043	319,177	267,353	198,270	136,229	148,922	170,377
Merchandise, all l. c. l. freight	36,954	36,043	29,667	22,773	15,234	14,351	14,345
Total tonnage	1,285,943	1,339,091	1,153,190	894,186	646,223	698,943	765,296

[1] Weight as delivered at original shipping point. In the case of freight transported over several different railways, each ton is counted only when transported by the first railway. Some traffic, reshipped under new billing without benefit of transit privileges or proportional rates, may be counted more than once.
[2] Preliminary.

Bureau of Agricultural Economics; compiled from reports of the Interstate Commerce Commission. Figures for earlier years appear in previous issues of the Yearbook.

Table 26.—*Exports of selected domestic agricultural products, annual 1910–11 to 1934–35*

Year beginning July	Butter	Cheese	Milk, condensed and evaporated	Eggs in the shell	Pork and its products, total [1]	Pork, fresh	Pork, pickled	Bacon, including Cumberland sides	Hams and shoulders, including Wiltshire sides	Lard, pure
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 dozen*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
1910–11	4,878	10,367	12,180	8,559	879,455	1,355	45,729	156,675	47,709	476,108
1911–12	6,092	6,338	20,643	15,406	1,071,952	2,598	56,321	208,574	204,044	532,256
1912–13	3,586	2,599	16,526	20,409	984,697	2,458	53,749	200,994	159,545	519,025
1913–14	3,694	2,428	16,209	16,149	921,913	2,668	45,543	193,964	165,882	481,458
1914–15	9,851	55,363	37,236	20,784	1,106,180	3,908	45,656	346,718	203,701	475,532
1915–16	13,487	44,394	159,578	26,396	1,462,697	63,006	63,461	579,809	282,209	427,011
1916–17	26,835	66,050	259,141	24,926	1,501,948	50,436	46,993	667,152	266,657	444,770
1917–18	17,736	44,303	528,759	18,969	1,692,124	21,390	33,222	815,294	419,572	392,506
1918–19	33,740	18,792	728,741	28,385	2,704,694	19,644	31,504	1,238,247	667,240	724,771
1919–20	27,156	19,378	708,463	38,327	1,762,611	27,225	41,643	803,667	275,456	587,225
1920–21	7,829	10,826	262,668	26,960	1,522,162	57,075	33,286	489,298	172,012	746,157
1921–22	7,512	7,471	277,311	33,762	1,516,320	25,911	33,510	350,549	271,642	812,379
1922–23	9,410	8,446	157,038	34,284	1,794,880	43,772	40,934	408,334	319,269	952,642
1923–24	5,425	3,938	213,613	32,832	1,934,189	49,113	37,469	423,500	381,564	1,014,898
1924–25	8,384	9,432	173,547	25,107	1,400,149	27,603	26,726	236,263	292,214	792,735
1925–26	5,280	4,094	135,865	27,931	1,172,685	15,867	29,126	186,153	220,014	695,445
1926–27	5,048	3,773	108,942	27,962	1,012,668	10,881	27,962	127,576	143,649	675,812
1927–28	3,965	2,873	108,943	22,832	1,046,306	11,059	31,650	126,977	127,819	716,398
1928–29	3,778	2,572	112,492	15,982	1,112,394	10,641	39,906	129,248	125,396	780,914
1929–30	3,582	2,339	101,572	14,234	1,138,588	18,768	39,809	132,967	130,318	787,160
1930–31	2,293	1,733	78,986	14,386	791,354	11,093	21,118	52,412	99,749	585,670
1931–32	1,578	1,564	65,623	3,519	679,748	9,270	15,229	[2] 25,576	[3] 69,334	542,639
1932–33	1,386	1,346	40,013	1,805	686,462	8,182	14,275	17,699	71,213	560,299
1933–34	1,416	1,253	38,088	2,008	705,981	28,299	19,069	23,841	71,488	546,997
1934–35 [4]	761	1,344	47,430	1,802	355,072	26,436	14,704	11,990	64,561	225,112

Year beginning July	Beef and its products, total [5]	Oleo oil	Cotton lint [6]	Linters [6]	Cottonseed cake and meal	Linseed cake and meal	Prunes	Raisins	Apples, fresh	Apples, dried	Apricots, dried
	1,000 pounds	*1,000 pounds*	*1,000 bales*	*1,000 bales*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 barrels*	*1,000 pounds*	*1,000 pounds*
1910–11	265,924	138,697	8,068	------	804,597	559,675	51,031	18,660	1,721	------	------
1911–12	233,925	126,467	11,070	------	1,293,690	596,115	74,328	19,949	1,456	------	------
1912–13	170,208	92,850	9,125	------	1,128,092	838,120	117,951	28,121	2,150	41,575	35,017
1913–14	151,212	97,017	9,522	------	799,974	662,869	69,814	14,766	1,507	33,566	17,402
1914–15	394,991	80,482	8,581	226	1,479,065	524,794	43,479	24,845	2,352	42,589	23,764
1915–16	457,556	102,646	5,917	251	1,057,222	640,916	57,423	75,015	1,466	16,219	23,940
1916–17	423,674	67,110	5,702	474	1,150,160	536,984	59,645	51,993	1,740	10,358	9,841
1917–18	600,132	56,603	4,455	186	44,681	151,400	32,927	54,988	635	2,603	5,230
1918–19	591,302	59,292	5,442	84	311,624	202,788	59,072	84,150	1,576	18,909	20,975
1919–20	368,002	74,529	7,035	52	449,573	336,336	114,066	86,857	1,051	11,819	26,768
1920–21	203,815	106,415	5,570	53	454,701	391,264	57,461	24,492	2,665	18,053	8,332
1921–22	222,462	117,174	6,592	126	532,721	484,059	109,398	49,639	1,094	12,431	16,736
1922–23	194,912	104,956	5,205	48	454,350	574,612	79,229	93,962	1,756	12,817	11,193
1923–24	185,081	92,965	5,784	115	250,366	560,114	136,448	88,152	4,098	30,323	38,777
1924–25	190,366	105,145	8,239	200	885,375	691,126	171,771	90,783	3,201	19,225	13,292
1925–26	152,320	90,410	8,110	102	716,505	589,166	151,405	135,027	3,672	24,833	18,132
1926–27	151,531	92,720	11,281	278	990,516	625,121	175,544	152,337	7,098	32,670	17,901
1927–28	106,595	64,851	7,890	230	664,523	606,304	260,625	193,099	3,144	21,704	23,684
1928–29	101,303	63,187	8,520	219	571,200	645,120	273,051	221,756	7,014	50,024	24,652
1929–30	102,080	61,088	7,096	143	338,240	624,960	142,989	128,697	3,426	23,769	19,101
1930–31	98,379	54,960	7,048	132	87,360	304,640	296,254	125,100	6,780	38,120	23,647
1931–32	79,482	43,762	8,989	145	430,080	443,520	243,935	122,213	6,010	31,557	37,622
1932–33	74,000	39,632	8,647	218	302,400	241,920	182,354	112,507	4,585	39,019	34,268
1933–34	78,515	27,429	8,366	216	147,840	546,560	202,832	93,954	4,086	43,182	36,616
1934–35 [4]	40,882	13,173	5,066	262	6,720	380,800	152,716	93,890	2,688	24,485	15,196

[1] Includes canned, fresh, salted, or pickled pork, lard, neutral lard, lard oil, bacon, and hams, Wiltshire and Cumberland sides.
[2] Includes "Wiltshire sides", beginning January 1932.
[3] Wiltshire sides included with "Bacon."
[4] Preliminary.
[5] Includes canned, cured, and fresh beef, oleo oil, oleo stock, oleomargarine, tallow, and stearin from animal fats.
[6] Bales of 500 pounds gross; lint cotton and linters not separately reported prior to 1915.

TABLE 26.—*Exports of selected domestic agricultural products, annual 1910–11 to 1934–35*—Continued

Year beginning July	Oranges [7]	Apricots, canned [8]	Pears canned [8]	Peaches, canned [8]	Pineapples, canned [8]	Grapes	Pears, fresh [8]	Grapefruit, fresh	Starch, including cornstarch	Cornstarch [9]
	1,000 boxes	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 boxes*	*1,000 pounds*	*1,000 pounds*
1910–11	1, 179	-------	-------	-------	-------	-------	-------	-------	158, 239	-------
1911–12	1, 197	-------	-------	-------	-------	-------	-------	-------	83, 645	-------
1912–13	1, 063	-------	-------	-------	-------	-------	-------	-------	110, 898	-------
1913–14	1, 559	-------	-------	-------	-------	-------	-------	-------	76, 714	-------
1914–15	1, 759	-------	-------	-------	-------	-------	-------	-------	107, 037	-------
1915–16	1, 575	-------	-------	-------	-------	-------	-------	-------	210, 185	-------
1916–17	1, 850	-------	-------	-------	-------	-------	-------	-------	146, 424	-------
1917–18	1, 240	-------	-------	-------	-------	-------	-------	-------	73, 883	38, 659
1918–19	1, 402	-------	-------	-------	-------	-------	-------	-------	143, 788	105, 727
1919–20	1, 619	-------	-------	-------	-------	-------	-------	-------	237, 609	163, 315
1920–21	2, 001	-------	-------	-------	-------	-------	-------	-------	135, 365	110, 514
1921–22	1, 641	-------	-------	-------	-------	[10] 173	-------	[10] 140	386, 873	348, 940
1922–23	1, 799	[10] 13, 809	49, 358	54, 624	21, 848	14, 022	36, 785	252	260, 796	254, 060
1923–24	2, 592	26, 576	38, 431	50, 374	25, 238	20, 257	50, 237	305	262, 842	255, 135
1924–25	2, 197	31, 360	53, 851	57, 390	26, 252	20, 302	41, 452	427	214, 247	209, 865
1925–26	2, 253	29, 547	75, 876	83, 160	37, 543	24, 268	71, 205	379	224, 569	208, 463
1926–27	3, 340	35, 896	66, 104	81, 896	37, 426	30, 791	73, 877	613	233, 111	212, 375
1927–28	2, 988	29, 013	52, 671	86, 634	51, 227	38, 819	51, 056	719	281, 388	275, 921
1928–29	4, 223	26, 249	82, 652	101, 438	47, 533	55, 638	82, 847	940	235, 660	231, 667
1929–30	3, 674	33, 235	54, 709	74, 470	46, 309	46, 158	62, 024	854	203, 343	200, 558
1930–31	3, 984	19, 024	74, 355	75, 763	35, 308	49, 799	134, 670	1, 222	104, 807	102, 886
1931–32	3, 534	23, 161	71, 570	66, 300	20, 920	27, 613	90, 702	1, 202	73, 071	71, 927
1932–33	3, 391	19, 504	60, 762	74, 999	15, 923	29, 352	119, 987	902	52, 969	52, 350
1933–34	3, 449	24, 315	78, 384	81, 464	21, 831	26, 689	111, 008	946	73, 922	73, 377
1934–35 [4]	4, 092	10, 549	71, 379	50, 419	19, 111	35, 712	100, 635	984	40, 468	39, 932

Year beginning July	Barley, including flour and malt [11]	Corn, including corn meal	Oats, including oatmeal	Rice, including flour, meal, and broken rice	Rye, including flour	Wheat, including flour	Tobacco, unmanufactured [12]	Glucose and grape sugar	Hops	Sugar, raw and refined [13]
	1,000 bushels	*1,000 bushels*	*1,000 bushels*	*1,000 pounds*	*1,000 bushels*	*1,000 bushels*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 sh. tons*
1910–11	9, 507	65, 615	3, 846	15, 575	40	71, 338	355, 327	181, 963	13, 105	28
1911–12	1, 655	41, 797	2, 678	26, 798	31	81, 891	379, 845	171, 156	12, 191	40
1912–13	17, 874	50, 780	36, 455	24, 801	1, 855	145, 159	418, 797	200, 149	17, 591	22
1913–14	6, 945	10, 726	2, 749	18, 223	2, 273	147, 955	449, 750	199, 531	24, 263	26
1914–15	28, 712	50, 668	100, 609	75, 449	13, 027	335, 702	348, 346	158, 463	16, 210	275
1915–16	30, 821	39, 897	98, 960	120, 695	15, 250	246, 221	443, 923	186, 406	22, 410	815
1916–17	20, 319	66, 753	95, 106	181, 372	13, 703	205, 962	411, 599	214, 973	4, 225	625
1917–18	28, 717	49, 073	125, 091	196, 363	17, 186	132, 579	289, 171	97, 858	3, 495	288
1918–19	26, 997	23, 019	109, 005	193, 128	36, 467	287, 402	629, 288	136, 230	7, 467	558
1919–20	34, 555	16, 729	43, 436	483, 385	41, 531	222, 030	648, 038	245, 264	30, 780	722
1920–21	27, 255	70, 906	9, 391	440, 855	47, 337	369, 313	506, 526	141, 954	22, 206	292
1921–22	27, 543	179, 490	21, 237	541, 509	29, 944	282, 566	463, 389	273, 982	19, 522	1, 001
1922–23	21, 909	96, 596	25, 413	370, 670	51, 663	224, 900	454, 364	162, 693	13, 497	375
1923–24	13, 913	23, 135	8, 796	227, 757	19, 902	159, 880	597, 630	148, 051	20, 461	135
1924–25	28, 543	9, 791	16, 777	112, 037	50, 242	260, 803	430, 702	139, 577	16, 122	251
1925–26	30, 449	24, 783	39, 687	48, 175	12, 647	108, 035	537, 240	170, 142	14, 998	300
1926–27	19, 655	19, 819	15, 041	304, 358	21, 697	219, 160	516, 401	148, 789	13, 369	114
1927–28	39, 274	19, 409	9, 823	309, 788	26, 346	206, 259	489, 996	145, 951	11, 812	106
1928–29	60, 295	41, 874	16, 251	392, 684	9, 488	163, 687	565, 925	123, 366	8, 836	128
1929–30	24, 054	10, 281	7, 966	289, 532	2, 600	153, 245	600, 181	101, 816	6, 793	79
1930–31	11, 443	3, 317	3, 123	281, 005	227	131, 475	591, 035	70, 571	5, 593	70
1931–32	5, 469	3, 969	4, 438	274, 716	909	135, 797	432, 361	51, 855	3, 817	54
1932–33	9, 399	8, 775	5, 361	177, 715	311	41, 211	399, 967	41, 829	2, 431	41
1933–34	6, 111	4, 965	1, 405	100, 819	21	37, 003	472, 630	51, 662	7, 588	60
1934–35 [4]	4, 125	2, 324	1, 147	122, 704	([14])	21, 537	374, 658	32, 310	6, 735	152

[4] Preliminary.
[7] Converted to boxes of 78 pounds.
[8] Given in value only prior to 1922–23.
[9] Included with "Starch" prior to 1917–18.
[10] Jan. 1 to June 30.
[11] Includes barley flour 1919–22. Barley flour not separately reported prior to 1919 nor since 1922.
[12] Includes stems, trimmings, and scrap tobacco.
[13] Includes maple sugar, 1919–34.
[14] Less than 500.

Bureau of Agricultural Economics; compiled from Foreign Commerce and Navigation of the United States, 1910–18, and Monthly Summary of Foreign Commerce of the United States, June issues 1919–35.

Conversion factors used: Corn meal, 1 barrel=4 bushels corn; oatmeal, 18 pounds=1 bushel oats; rye flour, 1 barrel=6 bushels rye; malt, 1.1 bushels=1 bushel barley; wheat flour, 1 barrel=1909–17, 4.7 bushels grain; 1918 and 1919, 4.5 bushels; 1920, 4.6 bushels; 1921–35, 4.7 bushels; apples, 3 boxes=1 barrel. The unit "1,000 pounds" in the columns of canned goods is presumed to be net weight, according to Government regulations.

TABLE 27.—*Imports of selected agricultural products, annual 1910–11 to 1934–35*

Year beginning July	Butter	Cheese	Milk, fresh [1]	Cream, fresh [2]	Beef and veal, fresh	Beef, canned [3]	Cattle hides, excluding calf and kip: Wet [4]	Cattle hides, excluding calf and kip: Dry [5]	Goatskins	Total hides and skins (except furs)	Wool, unmanufactured, including mohair, etc.
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
1910–11	1,008	45,569	-------	2,333	-------	-------	95,498	54,630	86,914	374,891	137,648
1911–12	1,026	46,542	-------	1,120	-------	-------	172,881	78,131	95,341	537,768	193,401
1912–13	1,162	49,388	-------	1,247	([6])	-------	185,447	82,595	96,250	572,197	195,293
1913–14	7,842	63,784	-------	1,773	180,137	-------	208,478	71,485	84,759	561,071	247,649
1914–15	3,828	50,139	-------	2,077	184,491	-------	241,340	93,001	66,547	538,218	308,083
1915–16	713	30,088	-------	1,194	71,102	-------	280,839	153,339	100,657	743,670	534,828
1916–17	524	14,482	-------	744	15,217	-------	225,363	161,237	105,640	700,207	372,372
1917–18	1,806	9,839	-------	712	25,452	-------	190,845	76,655	66,933	432,517	379,130
1918–19	4,131	2,442	2,592	([6])	36,670	127,135	220,695	33,182	89,005	448,142	422,415
1919–20	20,771	17,914	3,989	([6])	42,436	1,434	328,209	111,252	126,996	798,569	427,578
1920–21	34,344	16,585	4,391	([6])	41,956	3,081	173,759	24,814	41,728	352,193	318,236
1921–22	9,551	34,271	4,536	([6])	28,001	169	186,498	18,438	83,535	392,904	255,087
1922–23	15,772	54,555	5,148	([6])	32,481	2,393	346,613	58,770	89,401	682,893	525,473
1923–24	29,466	66,597	6,623	[7] 1,646	25,144	5,892	158,363	18,112	65,881	365,194	239,122
1924–25	7,189	61,489	6,418	4,765	12,419	10,060	184,934	14,376	65,956	387,447	284,706
1925–26	6,440	62,412	7,479	4,798	18,279	14,973	141,081	14,506	86,484	355,266	345,512
1926–27	10,710	89,782	6,106	5,273	22,098	32,158	145,651	11,287	83,571	368,876	271,128
1927–28	4,955	75,424	5,425	4,819	47,650	38,617	280,901	26,461	84,751	532,379	248,035
1928–29	3,299	84,606	5,016	3,173	62,481	73,191	202,489	13,859	94,486	447,384	270,937
1929–30	2,851	78,261	3,314	2,474	30,190	82,489	284,302	10,530	101,120	548,567	220,476
1930–31	1,329	57,972	1,190	844	3,551	16,480	87,526	3,581	80,830	265,854	149,557
1931–32	1,838	57,235	280	118	898	22,483	88,385	3,427	67,038	254,084	103,941
1932–33	991	55,923	33	52	709	31,186	58,192	2,064	54,391	211,548	52,304
1933–34 [8]	763	46,907	40	25	276	39,543	136,550	3,745	87,394	330,407	176,993
1934–35 [9]	22,393	48,446	23	1	5,038	69,535	86,156	411	60,702	211,801	122,788

Year beginning July	Hair of the Angora (mohair)	Cotton, unmanufactured [10]	Silk [11]	Tobacco, unmanufactured	Rubber and similar gums, crude	Coffee	Tea	Cocoa or cacao beans	Sugar, raw and refined	Molasses	Olives green or in brine
	1,000 pounds	*1,000 bales*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 short tons*	*1,000 gallons*	*1,000 gallons*
1910–11	-------	238	26,666	48,203	145,744	875,367	102,564	138,058	1,969	23,838	3,045
1911–12	-------	230	26,585	54,740	175,966	885,201	101,407	145,969	2,052	28,828	5,077
1912–13	-------	255	32,101	67,977	170,747	863,131	94,813	140,039	2,370	33,927	3,946
1913–14	-------	258	34,546	61,175	161,777	1,001,528	91,131	176,268	2,533	51,410	5,316
1914–15	-------	387	31,053	45,809	196,122	1,118,691	96,988	192,307	2,710	70,840	3,622
1915–16	-------	487	41,925	48,078	304,183	1,201,104	109,866	243,232	2,817	85,717	5,938
1916–17	-------	308	40,351	49,105	364,914	1,319,871	103,364	338,654	2,666	110,238	5,642
1917–18	-------	216	43,681	86,991	414,984	1,143,891	151,315	399,040	2,452	130,731	2,385
1918–19	-------	217	50,069	83,951	422,215	1,046,029	108,172	313,037	2,918	130,075	3,501
1919–20	-------	722	58,410	94,005	660,610	1,414,228	97,826	420,331	3,798	154,670	5,206
1920–21	-------	263	34,778	58,923	371,300	1,348,926	72,196	327,123	3,506	113,414	4,054
1921–22	-------	375	57,437	65,225	578,512	1,238,012	86,142	317,124	4,232	87,908	([12])
1922–23	[13] 7,220	494	63,188	75,786	810,028	1,305,188	96,669	381,508	4,367	161,135	([12])
1923–24	3,583	305	56,595	54,497	633,489	1,429,617	105,443	382,971	3,765	174,037	6,848
1924–25	2,404	324	70,270	76,870	824,434	1,279,570	92,779	382,570	4,337	215,778	5,901
1925–26	6,463	338	76,838	69,974	962,659	1,437,364	99,411	417,060	4,420	256,246	5,992
1926–27	6,547	400	85,162	92,983	993,272	1,444,847	97,402	425,184	4,420	260,259	5,212
1927–28	2,204	367	87,128	81,045	959,245	1,535,392	90,099	411,543	4,045	248,427	6,458
1928–29	3,134	476	90,662	79,284	1,252,130	1,435,070	92,635	419,243	4,753	296,550	6,955
1929–30	1,073	414	87,408	63,181	1,157,817	1,562,058	86,368	421,938	3,641	253,114	8,452
1930–31	474	107	87,861	75,425	1,048,758	1,728,569	87,148	415,442	3,287	217,001	7,429
1931–32	0	139	82,503	73,375	1,098,501	1,628,841	90,459	434,853	3,264	205,968	7,057
1932–33	113	133	76,768	59,545	789,186	1,458,161	94,808	476,421	2,951	145,450	4,674
1933–34 [8]	1,320	157	63,498	55,784	1,222,087	1,598,107	87,691	465,831	2,819	213,566	5,806
1934–35 [9]	16	116	61,104	58,270	981,606	1,552,049	83,572	539,076	3,368	251,040	6,822

[1] Included with condensed and reported in value only prior to 1918–19. Includes cream, fresh, 1918–19 to 1923–24. Beginning 1924–25 reported as milk, sweet, sour, and buttermilk.
[2] Included in "all other articles" prior to 1909–10.
[3] Reported in value only prior to 1918–19. Figures are imports for consumption, and include corned beef.
[4] Wet salted over 25 pounds.
[5] Dry salted over 12 pounds.
[6] Not separately classified.
[7] Beginning Jan. 1, 1924; 6 months' figure.
[8] Imports for consumption beginning 1933–34.
[9] Preliminary.
[10] Bales of 478 pounds net.
[11] Includes silk, raw or as reeled from cocoon, silk waste, and silk cocoons. Beginning 1933–34, silk waste excluded.
[12] Reported in value only.
[13] Beginning Sept. 22, 1922.

TABLE 27.—*Imports of selected agricultural products, annual 1910–11 to 1934–35*—Continued

Year beginning July	Bananas	Lemons [14]	Beans, dry	Onions	Tomatoes, fresh	Almonds in terms of shelled [15]	Peanuts in terms of shelled [15]	Walnuts in terms of shelled [15]	Copra [16]	Flaxseed
	1,000 bunches	*1,000 boxes*	*1,000 bushels*	*1,000 bushels*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 bushels*
1910–11	44,699	1,824	1,037	1,515	-------	15,523	18,834	33,619	37,817	10,499
1911–12	44,521	1,968	1,005	1,436	-------	17,231	11,248	37,214	64,581	6,842
1912–13	42,357	2,046	1,048	789	-------	13,856	14,989	17,213	34,268	5,294
1913–14	48,684	([12])	1,634	1,115	-------	15,027	38,726	20,800	45,437	8,653
1914–15	41,092	([12])	906	829	-------	13,679	19,338	20,490	90,547	10,666
1915–16	36,755	([12])	663	816	-------	14,546	25,407	23,733	110,078	14,679
1916–17	34,661	([12])	3,748	1,758	-------	19,916	32,385	23,839	247,036	12,394
1917–18	34,550	([12])	4,146	1,313	-------	20,845	75,463	16,252	486,996	13,367
1918–19	35,382	([12])	4,016	152	-------	25,615	20,425	9,057	301,965	8,427
1919–20	36,848	([12])	3,806	1,884	-------	28,533	128,390	28,961	218,522	23,392
1920–21	40,808	([12])	824	689	-------	15,861	46,202	15,902	192,246	16,170
1921–22	46,120	1,373	520	2,488	-------	28,036	9,678	35,174	249,722	13,632
1922–23	44,504	1,660	2,623	1,783	([6])	24,345	45,013	25,970	306,100	25,006
1923–24	44,935	1,018	886	1,406	[7] 50,838	24,207	50,683	26,428	299,774	19,577
1924–25	50,513	1,264	1,421	2,075	69,216	22,503	93,191	36,623	328,652	13,419
1925–26	58,550	1,247	1,271	2,194	82,448	19,686	36,026	31,698	392,759	19,354
1926–27	57,102	659	1,051	2,298	124,489	15,890	49,792	31,776	454,546	24,224
1927–28	64,029	1,308	2,465	1,399	113,357	18,496	63,783	20,347	456,158	18,112
1928–29	63,530	391	1,505	2,050	128,627	18,673	30,412	24,500	629,937	23,494
1929–30	65,909	1,229	2,534	918	139,886	19,956	9,941	20,228	493,456	19,652
1930–31	57,841	350	1,346	214	113,480	13,264	9,360	17,818	565,397	7,813
1931–32	51,785	176	222	665	122,215	8,338	1,535	13,042	445,741	13,850
1932–33	45,114	146	157	73	59,028	4,906	239	6,759	494,821	6,213
1933–34 [8]	43,096	47	146	80	46,254	3,412	400	5,682	653,182	17,901
1934–35 [9]	51,987	8	580	252	77,160	2,987	244	5,645	327,269	15,332

Year beginning July	Jute and jute butts, unmanufactured	Manila or abaca	Sisal and henequen	Eggs, whole, in the shell	Eggs and egg yolks, dried, frozen, or prepared	Whole eggs, dried	Whole eggs, frozen	Yolks, dried	Yolks, frozen	Egg albumen, dried	Egg albumen, frozen, prepared, and preserved
	1,000 long tons	*1,000 long tons*	*1,000 long tons*	*1,000 dozen*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
1910–11	65	74	118	1,573	433	-------	-------	-------	-------	-------	-------
1911–12	101	69	114	973	44	-------	-------	-------	-------	-------	-------
1912–13	125	74	154	1,367	228	-------	-------	-------	-------	-------	-------
1913–14	106	50	216	6,015	3,420	-------	-------	-------	-------	-------	-------
1914–15	83	51	186	3,047	8,572	-------	-------	-------	-------	-------	-------
1915–16	108	79	229	733	6,022	-------	-------	-------	-------	-------	-------
1916–17	113	77	143	1,110	10,318	-------	-------	-------	-------	-------	-------
1917–18	78	86	150	1,619	14,598	-------	-------	-------	-------	-------	-------
1918–19	53	68	153	848	9,085	-------	-------	-------	-------	-------	-------
1919–20	77	77	176	1,348	24,091	-------	-------	-------	-------	-------	-------
1920–21	90	52	159	3,316	28,768	-------	-------	-------	-------	([6])	-------
1921–22	62	44	72	1,224	16,540	-------	-------	-------	-------	7,388	-------
1922–23	85	98	98	535	14,821	-------	-------	-------	-------	3,213	-------
1923–24	84	98	97	426	[17] 14,830	[7] 544	[7] 1,106	[7] 522	[7] 1,210	6,642	[7] 636
1924–25	56	73	146	682	-------	1,884	8,751	4,281	4,151	3,257	1,106
1925–26	71	62	126	276	-------	1,305	12,647	6,004	5,662	4,490	5,119
1926–27	89	61	116	296	-------	1,132	8,114	4,468	4,601	3,859	3,967
1927–28	81	48	124	256	-------	575	611	3,486	1,229	2,361	553
1928–29	92	60	135	291	-------	2,133	12,616	5,130	4,581	2,898	610
1929–30	80	73	113	337	-------	1,839	9,824	7,819	3,475	4,363	955
1930–31	49	43	84	301	-------	822	113	6,069	1,052	2,219	2
1931–32	52	27	109	282	-------	543	2	1,920	443	1,722	0
1932–33	38	25	166	262	-------	19	([18])	1,595	403	1,424	0
1933–34 [8]	60	43	116	198	-------	7	81	1,809	308	361	0
1934–35 [9]	49	39	74	384	-------	377	5	3,116	1,006	1,140	0

[6] Not separately classified.
[7] Beginning Jan. 1, 1924; 6 months' figure.
[8] Imports for consumption beginning 1933–34.
[9] Preliminary.
[12] Reported in value only.
[14] Boxes of 74 pounds.
[15] Conversion factors used: almonds, 30 percent unshelled equals shelled; peanuts, 3 pounds unshelled equals 2 pounds shelled; walnuts, 42 percent unshelled equals shelled.
[16] Reported as "coconut meat broken, or copra, not shredded, desiccated or prepared" 1909–10 to 1921–22; 1922–23 to 1924–25 reported as "copra, not prepared", 1925–26 to date reported as "copra."
[17] July 1–Dec. 31, 1923.
[18] Less than 500.

Bureau of Agricultural Economics; compiled from Commerce and Navigation of the United States 1910–18, and Monthly Summary of Foreign Commerce, June issues, 1919–35.

TABLE 28.—*Gold value of the dollar, and dollar value of gold in London,*[1] *April 1933–March 1936*

Date	Gold value of the dollar	Dollar value of gold per ounce	
		Actual	Relative
1933	*Cents*	*Dollars*	
Apr. 1-15[2]	100.0	20.67	100.0
Apr. 3	100.2	20.62	99.8
Apr. 10	100.1	20.64	99.9
Apr. 17	100.0	20.67	100.0
Apr. 24	90.2	22.92	110.9
May 1	85.9	24.07	116.4
May 8	84.9	24.35	117.8
May 15	84.8	24.39	118.0
May 22	86.5	23.89	115.6
May 29	84.1	24.59	119.0
June 6	83.4	24.78	119.9
June 12	80.9	25.54	123.6
June 19	81.6	25.34	122.6
June 26	79.6	25.95	125.5
July 3	75.1	27.54	133.2
July 10	69.3	29.83	144.3
July 17	69.3	29.82	144.3
July 24	71.6	28.88	139.7
July 31	74.3	27.81	134.5
Aug. 8	74.0	27.92	135.1
Aug. 14	74.7	27.68	133.9
Aug. 21	73.2	28.23	136.6
Aug. 28	71.2	29.04	140.5
Sept. 5	69.5	29.74	143.9
Sept. 11	70.6	29.28	141.7
Sept. 18	65.8	31.41	152.0
Sept. 25	65.6	31.49	152.3
Oct. 2	64.8	31.92	154.4
Oct. 9	66.6	31.04	150.1
Oct. 16	71.8	28.78	139.2
Oct. 23	69.3	29.83	144.3
Oct. 30	65.6	31.52	152.5
Nov. 6	64.3	32.16	155.8
Nov. 13	62.3	33.19	160.6
Nov. 20	61.2	33.78	163.4
Nov. 27	63.1	32.75	158.4
Dec. 4	64.1	32.23	155.9
Dec. 11	63.2	32.73	158.3
Dec. 18	63.5	32.54	157.4
Dec. 27	63.7	32.43	156.9
1934			
Jan. 2	62.9	32.88	159.1
Jan. 8	64.1	32.24	156.0
Jan. 15	62.9	32.86	159.0
Jan. 22	62.0	33.33	161.2
Jan. 29	62.5	33.06	159.9
Feb. 5	59.9	34.51	167.0
Feb. 12	59.9	34.51	167.0
Feb. 19	59.8	34.56	167.2
Feb. 26	59.6	34.67	167.7
Mar. 5	59.5	34.72	168.0
Mar. 12	59.5	34.74	168.1
Mar. 19	59.5	34.74	168.1
Mar. 26	59.4	34.77	168.2
Apr. 3	59.5	34.75	168.1
Apr. 9	59.4	34.77	168.2
Apr. 16	59.5	34.75	168.1
Apr. 23	59.2	34.92	168.9
Apr. 30	59.2	34.89	168.8
May 7	59.3	34.84	168.6
May 14	59.5	34.75	168.1
May 22	59.4	34.82	168.5
May 28	59.4	34.79	168.3
June 4	59.5	34.75	168.1
June 11	59.3	34.87	168.7
June 18	59.4	34.78	168.3
June 25	59.4	34.77	168.2
July 2	59.4	34.79	168.3
July 9	59.4	34.78	168.3
July 16	59.5	34.76	168.2
July 23	59.5	34.76	168.2
July 30	59.4	34.77	168.2
Aug. 7	59.3	34.83	168.5
Aug. 13	58.6	35.25	170.5
Aug. 20	58.8	35.18	170.2
Aug. 27	58.6	35.28	170.7
Sept. 3	58.5	35.32	170.9
Sept. 10	58.7	35.22	170.4
Sept. 17	58.8	35.18	170.2
Sept. 24	58.8	35.18	170.2
Oct. 1	58.9	35.07	169.7
Oct. 8	59.0	35.05	169.6
Oct. 15	58.9	35.07	169.7
Oct. 22	59.1	34.99	169.3
Oct. 29	59.3	34.86	168.7
Nov. 5	59.3	34.83	168.5
Nov. 12	59.4	34.82	168.5
Nov. 19	59.4	34.80	168.4
Nov. 26	59.4	34.79	168.3
Dec. 3	59.4	34.79	168.3
Dec. 10	59.5	34.75	168.1
Dec. 17	59.4	34.77	168.2
Dec. 24	59.5	34.76	168.2
Dec. 31	59.4	34.81	168.4
1935			
Jan. 7	59.1	35.00	169.3
Jan. 14	59.4	34.79	168.3
Jan. 21	59.6	34.66	167.7
Jan. 28	60.5	34.16	165.3
Feb. 4	59.7	34.61	167.4
Feb. 11	59.5	34.74	168.1
Feb. 18	59.5	34.75	168.1
Feb. 25	59.2	34.94	169.0
Mar. 4	58.6	35.29	170.7
Mar. 11	58.7	35.22	170.4
Mar. 18	59.2	34.89	168.8
Mar. 25	59.5	34.76	168.2
Apr. 1	59.4	34.82	168.5
Apr. 8	59.2	34.94	169.0
Apr. 15	59.3	34.86	168.7
Apr. 23	59.4	34.79	168.3
Apr. 29	59.2	34.92	168.9
May 7	59.4	34.81	168.4
May 13	59.5	34.72	168.0
May 20	59.4	34.79	168.3
May 27	59.2	34.93	169.0
June 3	59.2	34.92	168.9
June 11	59.2	34.89	168.8
June 17	59.4	34.80	168.5
June 24	59.3	34.83	168.4
July 1	59.1	34.95	169.1
July 8	59.2	34.90	168.8
July 15	59.2	34.91	168.9
July 22	59.2	34.92	168.9
July 29	59.3	34.85	168.6
Aug. 6	59.2	34.93	169.0
Aug. 12	59.2	34.90	168.8
Aug. 19	59.2	34.89	168.8
Aug. 26	59.4	34.82	168.5
Sept. 2	59.4	34.78	168.3
Sept. 9	59.4	34.78	168.3
Sept. 16	59.4	34.77	168.2
Sept. 23	59.4	34.78	168.3
Sept. 30	59.4	34.77	168.2
Oct. 7	59.4	34.78	168.3
Oct. 14	59.4	34.77	168.2
Oct. 21	59.5	34.76	168.2
Oct. 28	59.4	34.77	168.2
Nov. 4	59.4	34.81	168.4
Nov. 12	59.4	34.81	168.4
Nov. 18	59.4	34.79	168.3
Nov. 25	59.4	34.79	168.3
Dec. 2	59.4	34.78	168.3
Dec. 9	59.4	34.77	168.2
Dec. 16	59.4	34.77	168.2
Dec. 23	59.4	34.78	168.3
Dec. 30	59.4	34.81	168.4
1936			
Jan. 6	59.4	34.80	168.4
Jan. 13	59.0	35.04	169.5
Jan. 20	59.3	34.83	168.5
Jan. 27	58.8	35.16	170.1
Feb. 3	58.6	35.30	170.8
Feb. 10	58.6	35.25	170.5
Feb. 17	58.7	35.22	170.4
Feb. 24	58.7	35.19	170.2
Mar. 2	58.7	35.24	170.5
Mar. 9	59.0	35.05	169.6
Mar. 16	59.0	35.06	169.6
Mar. 23	59.2	34.94	169.0
Mar. 30	59.3	34.83	168.5

[1] Based on the open-market price of gold in London, converted at the dollar-exchange rate at the "fixing of the gold price" each day at or near 11 a. m. (London time).
[2] Par.

Bureau of Agricultural Economics. Values are for Monday unless it falls on a holiday, when they are for the next business day.

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